DOI:
10.1016/j.neubiorev.2018.04.009

Accepted Manuscript

Title: Differences in the Theory of Mind profiles of patients with anorexia nervosa and individuals on the autism spectrum: A meta-analytic review

Authors: Jenni Leppanen, Felicity Sedgewick, Janet Treasure, Kate Tchanturia

PII: S0149-7634(17)30792-3
DOI: https://doi.org/10.1016/j.neubiorev.2018.04.009
Reference: NBR 3096

To appear in:

Received date: 28-10-2017
Revised date: 1-3-2018
Accepted date: 9-4-2018

Please cite this article as: Leppanen J, Sedgewick F, Treasure J, Tchanturia K, Differences in the Theory of Mind profiles of patients with anorexia nervosa and individuals on the autism spectrum: A meta-analytic review, *Neuroscience and Biobehavioral Reviews* (2010), https://doi.org/10.1016/j.neubiorev.2018.04.009

Differences in the Theory of Mind profiles of patients with anorexia nervosa and individuals on the autism spectrum: a meta-analytic review

Jenni Leppanen[1], Felicity Sedgewick[1], Janet Treasure[1], Kate Tchanturia[1,2]

[1] Department of Psychological Medicine, Institute of Psychiatry, Psychology, and Neuroscience, King's College London

[2] Illia State University, Department of Psychology, Tbilisi, Georgia

Corresponding author: Dr. Kate Tchanturia, King's College London, Institute of Psychiatry, Psychology, and Neuroscience, Department of Psychological Medicine, 103 Denmark Hill, London, SE5 8AF

Email: kate.tchanturia@kcl.ac.uk

Highlights

- Meta-analytic review of theory of mind in AN and ASD compared to HCs
- Performance was worse in AN and ASD relative to HC in all areas of theory of mind
- Compared to AN, autistic people performed worse on emotional theory of mind
- Performance in AN and ASD was similar in understanding simple social interactions
- Performance in AN and ASD was similar in implicit social attribution
- Potential processes underlying theory of mind profile in AN and ASD are discussed

1 Abstract

Background: This meta-analytic review examines the theory of mind profiles in both patients with anorexia nervosa (AN) and autistic individuals.

Methodology: The studies examining theory of mind were divided into the following categories: emotional theory of mind, understanding simple social situations, understanding complex social interactions, and implicit social attribution. All included studies investigated differences between healthy control (HCs) individuals and people with AN or autistic people. Differences in theory of mind profile between people with AN and autistic people were explored by conducting moderator analyses.

Results: People with AN and autistic people showed a similar theory of mind profile, but autistic individuals showed greater difficulties, particularly in emotional theory of mind.

Conclusions: Although both people with AN and autistic people have significant difficulties in all aspects of theory of mind relative to the HCs, some differences in the underlying profile may be present. However, due to relative paucity of theory of mind research among people with AN, further research is still needed before firm conclusion can be drawn.

Keywords: theory of mind, autism spectrum disorders, anorexia nervosa

2 Introduction

Autism spectrum disorder (ASD) is a life-long developmental condition characterised by difficulties with social interaction, repetitive and restricted behaviours and interests, and sensory sensitivities (American Psychiatric Association, 2013). Approximately 1 in 100 people in the UK population are on the autism spectrum (Brugha et al., 2011) with the most recent estimates of gender ratios standing at 3:1 male to female (Loomes et al., 2017). The most prominent model of autism postulates that autistic individual's[1] difficulties with social cognition centres on theory of mind abilities (Baron-Cohen et al., 1985). According to the model, autistic people have difficulties with social imagination, particularly in terms of understanding that other people have knowledge, thoughts, and motivations which are different to their own. This has been supported by a range of studies across the lifespan, including child (Colle et al., 2007; Happe, 1994) and adult participants (Baron-Cohen et al., 2001; Kleinman et al., 2001). Research has also shown that autistic people can have difficulties in facial affect recognition and production (Loveland et al., 2008; McIntosh et al., 2006), and in emotion recognition (Bal et al., 2010; Kuusikko et al., 2009), both of which are skills which play a significant role in our social interactions.

Anorexia nervosa (AN) is a life-threatening eating disorder that typically develops during adolescence (American Psychiatric Association, 2013). Despite the fact that majority of people diagnosed with AN are female, elevated prevalence of comorbid ASD symptoms

[1] Identity-first language (i.e., autistic person), opposed to person-first language (i.e., person with autism), is preferred by many autistic people and their allies. Therefore, in this article, the authors use predominantly identity-first language (Kenny, L., Hattersley, C., Molins, B., Buckley, C., Povey, C., Pellicano, E., 2016. Which terms should be used to describe autism? Perspectives from the UK autism community. Autism : the international journal of research and practice 20, 442-462.).

among people with AN has been recently documented (Bentz et al., 2017a; Huke et al., 2013; Vagni et al., 2016; Westwood et al., 2017a; Westwood et al., 2017c). Furthermore, experimental studies have reported that people with AN show similar difficulties in social cognition as autistic individuals. Recent meta-analytic reviews have shown that people with AN have difficulties in reception and production of facial affect (Bora and Kose, 2016; Caglar-Nazali et al., 2014). However, unlike in ASD, people with AN also show mood congruent, negative attentional and interpretation biases that may have some impact on these difficulties in social cognition (Ambwani et al., 2016; Cardi et al., 2013). Such biases in interpretation could lead to a differential profile in theory of mind in AN relative to ASD. Therefore, further investigation of similarities and differences in the social cognition profiles in AN and ASD is of interest.

The aim of the present review was to synthesise the existing literature investigating the theory of mind profile in autistic individuals and in those with AN. Specifically, we aimed to examine understanding of emotions in others, perspective taking, interpretation of social behaviour, and intuitive social attribution in these disorders, from early adolescence to adulthood. We also aimed to explore whether autistic people were significantly different from those with AN in their theory of mind performance.

3 Methods

3.1 Literature search

Two literature searches were conducted to identify articles that investigated theory of mind among autistic people and among those with AN. The following search terms were used to conduct the first search: *(("autism spectrum disorder") OR "Asperger syndrome") AND ("theory of mind" OR mentalizing OR “Reading the mind in the eyes” OR “reading the mind in the voice” OR “reading the mind in the video”)*. The second search was conducted using the search terms *("anorexia nervosa") AND ("theory of mind" OR mentalizing OR “Reading the mind in the eyes” OR “reading the mind in the voice” OR “reading the mind in the video”)*. In accordance with the PRISMA guidelines (Moher et al., 2009), the following electronic databases were used to conduct the literature searches: Pubmed, Scopus, Web of Knowledge, and OVID (PsycINFO, PsycARTICLES, MEDLINE, AGRIS, Embase). Additionally, the bibliographies of all included papers and related review articles were screened for any additional papers that were not found through the initial searches.

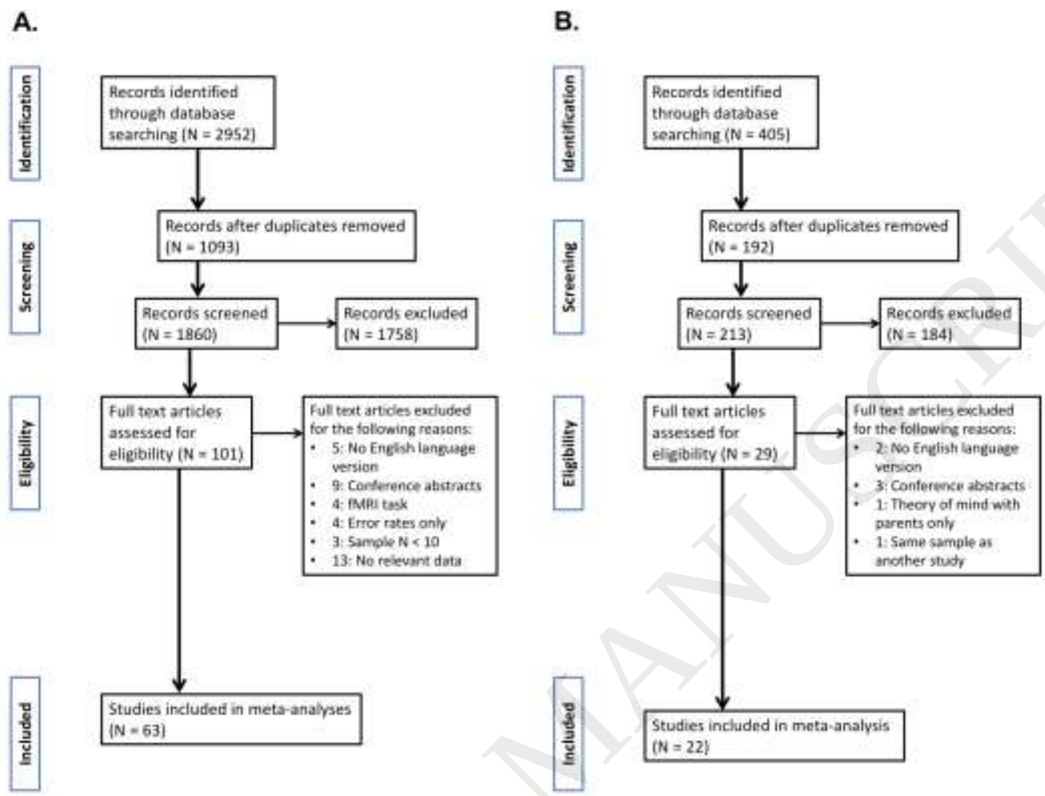
3.2 Eligibility criteria

To be included in the review the studies were required to 1) include a sample of adults or adolescents aged 12 years or older with a diagnosis of ASD, Asperger’s Disorder (AS), high functioning autism (HFA), or AN; 2) include an age-matched healthy comparison (HC) group; 3) assess theory of mind; 4) have at least ten participants in each group. Only studies assessing explicit theory of mind were included, and any studies using tasks in which theory of mind ability was inferred from eye movements or reaction times were excluded. Studies in which only young children took part were not included as AN is often diagnosed in early adolescence or later, and thus comparing young children with ASD and AN would not be possible. Additionally, studies that used self-report questionnaires or parental report measures to assess theory of mind were not included; nor were studies that used tasks that produced error rates, such as the Penny Hiding Game, because the outcome measure had the opposite direction compared to other included tasks making statistical comparisons difficult. To reduce heterogeneity in the sample, studies that assessed theory of mind during functional magnetic resonance imaging (fMRI) or positron emission tomography were not included. This was done because the tasks often need to be substantially amended to be used in such contexts, making comparisons with behavioural versions of similar tasks difficult. Finally, we used the following definition of theory of mind by Frith and Frith (2005): Theory of mind refers to the ability infer information about others' emotions, intentions, knowledge, and beliefs from social interaction or given information. Therefore, we did not include studies that only investigated recognition of basic emotions, but studies that required the identification of complex emotions or emotional mental states, such as frustration, were included.

3.3 Study selection

The study selection and screening flow charts are presented in Figures 1A,B. The literature search and initial screening of the articles based on title and abstract was conducted by two of the authors. Inclusion of papers following initial screening was decided by the whole team in consensus meetings. If there was any uncertainty about inclusion of certain articles they were brought to the whole team for further discussion.

Figure 1. Study selection flow charts



A. The study selection flow chart of studies investigating theory of mind in autism spectrum disorders. B. The study selection flow chart of studies investigating theory of mind in anorexia nervosa.

After initial screening, 101 full text articles investigating theory of mind in ASD were assessed for eligibility (Figure 1A). After this screening, five articles were excluded because we were unable to obtain an English language version of the papers, and nine articles were excluded for being conference abstracts. After further screening four publications were excluded for collecting theory of mind data during an fMRI scan, four papers were excluded for reporting error rates or inferring theory of mind from reaction times, and another three were excluded for including a sample of less than ten participants. Fourteen papers did not report the relevant data in the text or supplementary materials, and the corresponding authors of these papers were contacted to gain access to the data. One author, White et al. (2014), provided data via personal correspondence. Finally, 63 articles investigating the theory of mind profile in ASD were included in the review.

Following initial screening, 29 papers investigating theory of mind in people with AN were assessed further (Figure 1B). Two papers were excluded because we were unable to obtain an English language version of the paper, and another three were excluded because they were conference abstracts. One paper was excluded because the task involved assessing theory of mind used specifically in interactions with the participants' parents and was thus deemed to be too specific and another was excluded for including the same sample as a previous study from the same group. One paper did not provide the relevant data in the text or supplementary materials, but the corresponding author, Harrison et al. (2010b), provided the data through personal correspondence. The final sample included 22 papers that were included in the review.

3.4 Data collection and synthesis

In addition to sample sizes, means and standard deviations from the theory of mind tasks were extracted from the included studies. If a study reported standard errors, standard deviations were estimated with the following formula: $SD = SE * \sqrt{N}$. The extracted data was used to calculate standardised mean differences between the patient and HC samples, which were then entered into four separate meta-analyses exploring the theory of mind profile in individuals with ASD or AN. To explore any potential between-study heterogeneity, additional data regarding age, the IQ of the patient group, the proportion of male participants in the sample, and the type of tasks used to assess theory of mind was extracted.

3.5 Theory of mind tasks

The theory of mind tasks used in each study are summarised in Table 1. A wide range of different tasks were used to assess theory of mind and these tasks were divided into four separate categories representing different aspects of theory of mind: emotional theory of mind, understanding of simple social interactions, understanding of complex social interactions, and implicit social attribution. . The tasks were categorised according to methodological similarities as judged by the authors.

3.5.1 Emotional theory of mind tasks

Forty-four studies used the Reading the Mind in the Eyes task (RMET) to assess *emotional theory of mind* (Baron-Cohen et al., 1997b). In the RMET participants are presented with images of eyes and are then asked to identify the emotion or complex mental state the eyes are trying to convey by selecting the appropriate response from four options presented on the screen. Five studies used adapted versions of the same task, the Reading the Mind in the Voice task (RMVT) or the Reading the Mind in the Film task (RMFT) (Golan et al., 2006; Rutherford et al., 2002). In these tasks participants are presented with a short verbal or film excerpt, and are asked to identify the emotion that is being conveyed in a similar manner to the RMET. Two studies used the Levels of Emotional Awareness Scale (LEAS), in which participants are presented with short scenarios to assess their awareness of their own and other's emotions (Lane et al., 1990). Another two studies used the Emotions category of the Movie for the Assessment of Social Cognition (MASC), in which participants are presented with short films and asked to identify the emotion the characters in the films are portraying (Dziobek et al., 2006a). Additional measures used to assess emotional theory of mind included the Arena of Emotions (AoE) (Rosenblau et al., 2015) and the emotions subscale of the Animated Theory of Mind test (A-ToM) (Schaller and Rauh, 2017), which are similar to the MASC, and the Computerised Theory of Mind test (C-ToM) (Shamay-Tsoory, 2008), which was based on the RMET but also utilised gaze direction. The theory of mind score was calculated from the number of correct responses.

3.5.2 Understanding of simple social interactions

Tasks that were grouped into the *understanding of simple social interactions* category all assessed participants' accuracy of detecting mistakes in given social scenarios or stories. Thirteen studies used the Faux Pas test to assess understanding of simple social interactions (Gregory et al., 2002; Stone et al., 1998). The task involves participants reading stories and detecting whether the characters commit social faux pas or mistakes. Nine studies used a similar story task, the False Belief test, in which participants were asked about the characters' false beliefs due to changing social situations (Baron Cohen, 1985; Baron-Cohen, 1989). Other tasks used to assess understanding of simple social interactions included the theory of mind subscale of the Developmental NEuroPSYchological Assessment (NEPSY-II) (Korkman, 2007a, b), the cognitive subscale of the A-ToM (Schaller and Rauh, 2017), the Hint Task (Corcoran et al., 1995), a Theory of Mind Scale (Wellman and Liu, 2004), and the Dewey Story Test (DST) (Dewey, 1998), all of which assessed understanding of other's perspectives and false beliefs. In each task participants were asked to answer either multiple-choice or open-ended comprehension questions after each scenario. The answers were either scored correct or incorrect and the theory of mind score was calculated from the number of correct responses.

3.5.3 Understanding of complex social interactions

The tasks that were grouped into the *understanding of complex social interactions* category involved more than spotting simple social faux pas or mistakes. The tasks included understanding of sarcasm, jokes, white lies, double bluff, and other types of non-literal social interaction. Fifteen studies used the Strange Stories Task (SST) to assess understanding of complex social interactions (Happe, 1994) and six studies used the full MASC to assess understanding of various types of social scenarios (Dziobek et al., 2006a). The other tasks used to assess understanding of complex social interactions included the complex interaction subscale of the C-ToM task (Shamay-Tsoory, 2008), Cartoons, Commercials, various types of stories, the Social cognition and object relation (SCORS) task (Westen, 1995), and the Awareness of Social Inference Test (TASIT) (McDonald et al., 2003), all of which assessed participants' ability to understand complex social interactions. In all tasks the scenarios were followed by either multiple-choice or open-ended comprehension questions. In tasks other than the SST, participants' answers were either scored correct or incorrect and the theory of mind score was a sum of the number of correct responses. In the SST participants' responses to the open-ended questions could also be scored as partially correct if they gave some indication of understanding the character's thoughts, emotions, or mental states. The participants' answers were scored 2 if they were correct, 1 if they were partially correct, and

0 if they were incorrect, and the final theory of mind scores from the SST was a sum of the scores from each story.

3.5.4 Implicit social attribution

Ten studies used the Smith-Happé animations (SHA), four studies used Happé's cartoons, and another two studies used the Social Attribution Task (SAT) to assess *implicit social attribution* (Abell et al., 2000; Heider and Simmel, 1944; Klin, 2000). Other tasks used to assess implicit social attribution included cartoons, the narrative version of the Projective Imagination Test (PIT), the Thematic Apperception Test (TAT), and a reading task (Blackshaw et al., 2001; Murray, 1943). All tasks required participants to provide verbal descriptions of the stimuli they were given and the number of theory of mind terms used in descriptions formed the theory of mind score. The SHA task could also involve participants categorising the videos into three separate categories representing random movements, simple interactions, and complex interactions between the stimuli. In these studies, the number of correct categorisations formed the theory of mind score. Despite of the multiple-choice aspect of this task, it is believed to assess implicit social attribution because of the nature of the stimuli, which consist of silent videos showing complex interactions between two triangles.

3.6 Statistical analysis

All statistical analyses were conducted with R (R Core Team, 2015). Unbiased Hedges' g effect size estimates (Hedges, 1981), along with 95% confidence intervals were calculated to estimate differences between the patient and HC groups in theory of mind. The effect size estimates were interpreted as small (≥ 0.20), medium (≥ 0.50), and large (≥ 0.80) (Hedges, 1981).

The user-contributed package Metafor was used to conduct all statistical analyses including meta-analyses, meta-regressions, and publication bias analyses (Viechtbauer, 2010). Because some of the studies included more than one measure of theory of mind or compared two different groups of patients against the same control group, multivariate random effects meta-analyses were conducted using the *rma.mv* function. The multivariate meta-analysis accounts for the covariance that arises from the same sample being entered into the analysis more than once, allowing for investigation into differences between various measures of theory of mind.

Cochran's Q and I^2 statistics were calculated to examine between-study heterogeneity. To examine if studies with autistic people and people with AN were significantly different from each other when compared to a HC group, a moderator analysis with the diagnostic group (ASD, AN) was conducted. Additionally, where significant between-study heterogeneity was present, meta-regressions were conducted with the following moderators: study quality score, age, the type of task used, and estimated IQ of the patient group. All moderators were entered into the same model to investigate the impact of each on the heterogeneity while holding other moderators constant. If any moderators were highly correlated with each other they were automatically dropped from the meta-regression.

The presence of bias was explored by examining each study using the Study Quality Assessment Tool for Case-Control Studies developed by the United States National Institute of Health. Two authors, J.L. and F.S. independently assessed each study using the tool and rater agreement was calculated. If both raters gave a study a poor rating, that is the study failed to meet three or more of the criteria, it was excluded from any subsequent analysis. If there was any substantial disagreement between the raters, the study causing the disagreement was brought to the whole team for further assessment. Study quality scores, proportion of criteria met, were then calculated for each study and included in the subsequent meta-regressions. Standardised residuals and Cook's distance values of each study were computed to investigate if any study was substantially different from the others and thus, a potential outlier. Any study with the z-score of the standardised residual over 1.96 and Cook's distance over 1, was inspected further (Cook and Weisberg, 1982; Viechtbauer and Cheung, 2010) The presence of publication bias in each meta-analysis The presence of publication bias was explored by conducting Begg's rank correlation test of funnel plot asymmetry (Begg and Mazumdar, 1994).

4 Results

4.1 Study characteristics

The main characteristics of each study are summarised in Table 1. The SMD column represents the effect size estimate of the difference between the patient and HC groups in theory of mind performance in each study. Positive effect sizes indicate that the AN/ASD group performed better than the HC group, while negative effect sizes indicate that the HC group outperformed the AN/ASD group.

Table 1. Characteristics of studies investigating theory of mind in AN and ASD.

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
Baron-Cohen et al. (1997a)	HFA/AS = 16 males = 13	28.6 (9.7)	WAIS-R = 105.31 (13.0)	RMET (old version)	-1.47 [-2.08, -0.85]
	HC = 50 males = 25	30.0 (9.12)	Not measured		
Baron-Cohen et al. (1997c)	HFA/AS = 16 males = 13	28.6 (9.7)	FSIQ = 105.31 (13.0)	RMET	-1.36 [-2.13, -0.59]
	HC = 16 males = 13	30.0 (9.12)	NART = 100.0 (10.0)		
Baron-Cohen et al. (2001)	HFA/AS = 15 males = 15	29.7 (14.5)	WAIS-R = 115.0 (16.1)	RMET	-1.69 [-2.53, -0.84]

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
	HC = 14 males = 14	28.0 (9.0)	WAIS-R = 116.0 (6.4)		
Baron-Cohen et al. (2015)	ASD (M) = 178 males = 178 HC (M) = 152 males = 152	39.88 (11.56) 37.70 (12.62)	NR NR	RMET	-0.34 [-0.56, -0.13]
	ASD (F) = 217 males = 0 HC (F) = 168 males = 0	39.88 (11.80) 39.15 (10.82)	NR NR	RMET	-0.69 [-0.89, -0.48]

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
Beaumont and Newcombe (2006)	HFA/AS = 20 males = 16	27.7 (12.9)	NART = 107.8 (8.1)	TAT	-0.42 [-0.72, -0.12]
	HC = 20 males = 16	27.7 (11.9)	NART = 106.1 (8.7)	Commercials	-0.85 [-1.50, -0.21]
Begeer et al. (2010)	HFA = 34 males = 26	16.0 (4.0)	WISC-III 108.5 (21.1)	Reading task	-0.77 [-1.27, -0.28]
	HC = 34 males = 27	16.0 (3.0)	WISC-III = 105.8 (18.3)		
Beversdorf et al. (1998)	ASD = 10 males = 7	30.8 (9.3)	WAIS-R = 109.7 (16.2)	FBT	-0.91 [-1.77, -0.04]

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
	HC = 13 males = 8	30.6 (12.8)	WAIS-R = 117.3 (11.2)		
Blackshaw et al. (2001)	AS = 25 males = 20 HC = 18 males = 7	22.7 (6.8) 31.39 (7.85)	NART = 93.33 (11.5) NART = 109.5 (10.7)	PIT	-0.75 [-1.38, -0.12]
Bowler (1992)	AS = 15 males = 13 HC = 15 males = 7	26.7 (8.4) NR	WAIS = 86.8 (11.4) Not measured	FBT	-0.46 [-1.19, 0.26]

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
Brewer et al. (2017)	ASD = 163 males = 113	27.0 (11.8)	WASI-II: PRI = 108.7 (13.5) WASI-II: VCI = 103.0 (15.0)	FPT	-0.60 [-0.88, -0.33]
				SST	-0.73 [-1.00, -0.45]
	HC = 80 males = 24	26.1 (10.2)	WASI-II: PRI = 106.4 (12.1) WASI-II: VCI = 111.2 (13.9)	SHA	-0.24 [-0.47, -0.01]
Brown and Klein (2011)	HFA/AS = 16 male:female = 3:1 HC = 16 male:female = 3:1	25.8 (7.9) 26.6 (7.0)	WAIS: vocabulary score = 12.56 (3.1) WAIS: vocabulary score = 14.19 (2.7)	SAT	-1.28 [-1.91, -0.66]

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
Brunsdon et al. (2015)	ASD = 181 male:female = 4.48:1	13.49 (0.69)	WASI = 90.0 (20.3)	FBT	-0.52 [-0.76, -0.29]
	HC = 160 male:female = 2.20:1	12.79 (1.10)	WASI = 101.9 (15.1)	SHA	-0.24 [-0.92, 0.44]
Callenmark et al. (2014)	ASD = 19 males = 13	15.1 (1.6)	WISC/WAIS: vocabulary = 8.8 (2.6)	DST	-0.66 [-1.31, -0.001]
	HC = 19 males = 13	15.3 (1.7)	WISC/WAIS: vocabulary = 8.8 (2.6)		

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
Craig et al. (2004)	AS = 17 males = 15	24.1 (6.7)	NART = 104.8 (7.1)	RMET	-1.42, [-2.19, -0.66]
	HC = 16 males = 11	19.4 (8.4)	NART = 110.3 (9.9)	Hint task	-1.60 [-2.38, -0.81]
Crane et al. (2013)	ASD = 28 males = 14	41.6 (16.5)	WASI = 117.2 (13.5)	SST	-0.58 [-1.11, -0.04]
	HC = 28 males = 14	40.5 (17.2)	WASI = 115.1 (11.7)		
Demurie et al. (2011)	ASD = 13 males = 12	14.4 (1.2)	TIQ = 101.5 (11.6) VIQ = 98.0 (11.9)	RMET	-0.90 [-1.65, -0.15]

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
	HC = 18 males = 14	13.9 (1.7)	PIQ = 105.2 (14.3) Not measured		
(Dziobek et al., 2006a)	AS = 21 males = 19 HC = 20 males = 18	41.6 (10.4) 39.9 (12.6)	WAIS = 112.0 (6.1) WAIS = 124.0 (6.3)	RMET	-1.50 [-2.19, -0.81]
				SST	-0.77 [-1.42, -0.12]
				MASC	-2.24 [-3.04, -1.44]
Dziobek et al. (2006b)	AS = 17 males = 14	41.4 (9.9)	WAIS-R = 113.0 (6.0)	MASC - Emotions	-1.70 [-2.48, -0.91]

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
	HC = 17 males = 15	40.2 (13.0)	WAIS-R = 115.0 (5.0)	MASC - Total	-2.31 [-3.18, -1.45]
Flood et al. (2011)	AS = 26 males = 22 HC = 24 males = 19	13.5 (1.4) 13.3 (1.1)	NR NR	SST	-0.70 [-1.28, -0.13]
Golan et al. (2006)	ASD = 22 males = 17 HC = 22 males = 18	29.0 (9.8) 25.4 (9.5)	WASI = 114.2 (10.8) WASI = 116.5 (11.0)	RMFT	-1.30 [-1.95, -0.65]

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
Golan et al. (2007)	HFA/AS = 50 males = 40	27.5 (8.5)	WASI = 113.8 (11.5)	RMET	-1.16 [-1.69, -0.63]
	HC = 22 males = 17	24.3 (7.7)	WASI = 114.5 (9.9)	RMVT	-1.34 [-1.88, -0.80]
Gonzalez-Gadea et al. (2013)	AS = 23 males = 15	33.0 (9.8)	WAT = 37.4	RMET	-0.13 [-0.72, 0.46]
	HC= 21 males = 11	38.2 (14.4)	WAT = 37.1	FPT	-1.34 [-1.99, -0.69]
Grainger et al. (2014)	ASD = 18 males = 13	29.0 (10.3)	WASI = 112.3 (15.0)	SHA	-0.83 [-1.44, -0.23]
	HC = 18 males = 11	30.4 (14.6)	WASI = 114.9 (10.5)		

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
Heavey et al. (2000)	ASD = 16 males = 15	34.7 (9.5)	WAIS-R = 89.6 (11.7)	SST	-1.55 [-2.36, -0.75]
	HC = 15 males = 15	30.7 (8.1)	WAIS-R = 95.5 (14.7)	AMT	-1.72 [-2.55, -0.90]
Jolliffe and Baron-Cohen (1999)	AS/ASD = 34 males = 30	29.2 (7.8)	WAIS-R = 106.1 (13.9)	SST	-1.53 [-2.18, -0.88]
	HC = 17 males = 15	30.0 (9.1)	WAIS-R = 106.4 (12.7)		
Kleinman et al. (2000)	ASD = 24 males = 21	31.4 (8.3)	NR	RMET	-0.61 [-1.19, -0.03]
	HC = 24 males = 10	22.3 (5.8)	NR	RMVT	-1.29 [-1.91, -0.66]

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
Klin (2000)	HFA/AS = 40 males = NR HC = 20 males = NR	19.7 (11.3) 20.2 (7.4)	WAIS = 96.8 (23.3) WAIS = 103.1 (18.0)	SAT	-1.56 [-1.83, -1.30]
Kristen et al. (2014)	ASD = 20 males = 15 HC = 20 males = 14	28.3 (11.6) 29.3 (11.1)	Culture-Free IQ = 100.8 (22.1) Culture-Free IQ = 103.9 (14.1)	RMET	-0.65 [-1.29, -0.02]
				SST	-1.21 [-1.88, -0.53]
Lahera et al. (2014)	AS = 22 males = 18	21.9 (6.7)	NR	RMET	-1.64 [-2.30, -0.99]
				MASC	-1.34 [-1.97, -0.72]

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
	HC = 26 males = 17	22.9 (4.8)	NR	SST	-1.63 [-2.28, -0.97]
Lai et al. (2012)	ASD (M) = 32 males = 32 HC (M) = 32 males = 32	27.0 (7.2) 28.7 (5.9)	Full IQ = 113.7 (15.1) Full IQ = 116.3 (11.8)	RMET	-0.87 [-1.38, -0.36]
	ASD (F) = 32 males = 0 HC (F) = 32 males = 0	28.1 (8.2) 27.6 (6.3)	Full IQ = 114.1 (15.5) Full IQ = 119.7 (8.4)	RMET	-1.13 [-1.65, -0.60]
Lehnhardt et al. (2011)	HFA = 39	31.1 (8.9)	Full IQ = 127.9 (13.2)	RMET	-0.98 [-1.45, -0.51]

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
	males = 25				
	HC = 39 males = 25	31.2 (8.1)	Full IQ = 133.3 (11.6)		
Lever and Geurts (2015)	ASD = 118 males = 83	47.6 (14.9)	WAIS: vocabulary = 114.8 (16.9)	FPT	-0.41 [-0.67, -0.15]
	HC = 118 males = 83	47.7 (15.4)	WAIS: vocabulary = 114.3 (15.3)		
(Lind et al., 2014)	HFA = 27 males = 21	35.5 (13.2)	WASI = 112.4 (16.4)	SHA	-0.62 [-1.26, 0.02]
	HC = 29	33.3 (16.2)	WASI = 114.1 (11.0)		

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
	males = 22				
Lombardo et al. (2007)	ASD = 30 males = 23 HC = 30 males = 23	29.1 (7.4) 29.9 (78)	WASI = 117.2 (13.1) WASI = 117.1 (8.7)	RMET	-0.60 [-1.11, -0.08]
Lugnegard et al. (2013)	AS = 53 males = 26 HC = 50 males = 19	27.3 (4.1) 28.8 (9.3)	WAIS: vocabulary = 10.4 (2.3) WAIS: vocabulary = 9.9 (2.1)	RMET	-0.28 [-0.67, 0.10]
				SHA	-0.57 [-1.33, 0.19]
Marsh and Hamilton (2011)	HFA/AS = 18 males = NR	33.0 (10.9)	WAIS: Verbal = 112.9 (16.6)	SHA	-0.76 [-1.52, -0.01]

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
			WAIS: Performance = 104.4 (18.0)		
	HC = 19 males = NR	32.2 (10.1)	WAIS: Verbal = 112.5 (13.8) WAIS: Performance = 113.4 (13.9)		
Martin and McDonald (2004)	AS = 14 males = 13	19.6 (1.7)	WAIS-III: vocabulary = 10.4 (3.3)	PIT	-0.94 [-1.64, -0.25]
	HC = 24 males = 14	19.8 (3.4)	WAIS-III: vocabulary = 12.8 (2.7)		
Martinez et al. (2017)	ASD = 19 males = 15	22.7 (4.1)	WAIS = 108.6 (16.9)	MASC	-1.73 [-2.12, -1.33]

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
	HC = 20 males = 17	23.4 (3.6)	WAIS = 108.9 (11.0)		
Muller et al. (2016)	ASD = 33 males = 27	15.6 (1.9)	WISC = 101.1 (14.4)	RMET	-0.37 [-0.91, 0.16]
				MASC	-0.87 [-1.43, -0.31]
	HC = 23 males = 14	16.3 (2.4)	WISC = 109.8 (15.1)		
Murray et al. (2017)	ASD = 20 males = 20	30.6 (6.5)	WAIS: verbal = 105.1 (17.0)	RMET	-0.53 [-1.26, 0.01]
				SST	-0.61 [-1.24, 0.03]

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
	HC = 20 males = 19	30.7 (6.3)	WAIS: verbal = 112.3 (11.5)	SHA	-0.79 [-1.33, -0.25]
Oakley et al. (2016)	ASD = 19 males = 14	30.9 (11.9)	WASI = 108.5 (11.7)	MASC	
	HC (alexithymia-matched) = 24 males = 15	30.1 (12.2)	WASI = 109.8 (15.7)	RMET	-0.10 [-0.70, 0.51]
Pedreno et al. (2017)	HFA = 35 males = 34	18.6 (6.4)	WAIS-III/WISC = 100.0 (15.6)	RMET	-0.62 [-1.10, -0.14]
				FPT	-0.78 [-1.26, -0.29]
	HC = 35 males = 34	19.4 (6.2)	WAIS-III/WISC = 115.2 (10.7)	SST	-1.10[-1.61, -0.60]

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
Robinson et al. (2017)	ASD = 24 males = 20 HC = 24 males = 20	14.0 (25.1) 14.0 (25.3)	WASI = 104.3 (11.8) WASI = 103.6 (9.9)	RMET	-0.64 [-1.22, -0.06]
Rosenblau et al. (2015)	ASD = 28 males = 18 HC = 23 males = 17	33.1 (8.5) 32.4 (8.9)	MWT = 113.0 (16.4) MWT = 108.0 (12.9)	AoE	-0.88 [-1.46, -0.30]
				RMET	-0.72 [-1.29, -0.16]
Rutherford et al. (2002)	HFA/AS = 19 males = 17	29.0 (14.5)	WAIS = 107.9 (12.7)	RMVT	-1.02 [-1.69, -0.36]

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
	HC = 20 males = 17	36.0 (10.7)	WAIS = 101.0 (7.3)		
Samson and Hegenloh (2010)	AS = 19 Males = 47.4% HC = 109 males = 38.5%	27.8 (8.3) 25.0 (5.7)	NR NR	Cartoons	-0.78 [-1.28, -0.29]
Sato et al. (2017)	ASD = 19 males = 14 HC = 19 males = 14	28.1 (9.0) 23.3 (3.8)	WAIS = 112.3 (13.7) WAIS = 114.8 (7.0)	RMET	-0.89 [-1.55, -0.22]

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
Schaller and Rauh (2017)	ASD = 23 males = 23	15.7 (1.3)	Full IQ = 105.7 (11.5)	RMET	-1.17 [-1.80, -0.53]
				A-ToM (recognition of emotions being conveyed)	-0.70 [-1.30, -0.10]
				A-ToM (recognition of false beliefs)	-0.87 [-1.48, -0.26]
	HC = 22 males = 22	15.9 (1.0)	Full IQ = 103.8 (11.1)	FBT	-0.41 [-1.00, 0.18]
				MASC	-0.78 [-1.38, -0.17]

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
Schneider et al. (2013)	HFA = 18 males = 15	27.8	WASI = 112.6	ToM Scale	-0.66 [-1.35, 0.03]
	HC = 16 males = 13	31.2	WASI = 113.9	SST	-0.61 [-1.30, 0.08]
Schuwerk et al. (2015)	ASD = 18 males = 12	24.1 (7.0)	MWT = 104.3 (18.0) Culture-Fair IQ = 91.4 (21.7)	RMET	-1.18 [-1.88, -0.49]
	HC = 19 males = 13	25.3 (3.8)	MWT = 102.5 (11.9) Culture-Fair IQ = 98.3 (18.3)	SST	-0.29 [-0.94, 0.36]

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
Segura et al. (2015)	ASD = 21 males = 20 HC = 10 males = 10	19.7 (7.8) 18.2 (1.4)	WAIS = 102.0 (11.0) WAIS = 110.0 (10.0)	RMET	-0.53 [-1.30, 0.23]
				FPT	-0.41 [-1.17, 0.35]
				SST	-1.07 [-1.87, -0.27]
Senju et al. (2009)	AS = 19 males = NR HC = 17 males = NR	36.8 (14.3) 39.6 (11.7)	WAIS-III = 115.6 (14.9) WAIS-III = 115.3 (11.0)	FBT	-0.52 [-1.18, 0.15]
				SST	-0.25 [-0.90, 0.41]

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
Shamay-Tsoory (2008)	HFA/AS = 18 males = 17	21.9 (6.3)	NR	C-ToM (cognitive theory of mind)	-0.77 [-1.42, -0.12]
	HC = 21 males = 15	23.4 (6.3)	NR	C-ToM (recognition of fortune in others, e.g. gloating)	-0.78 [-1.44, -0.13]
Spek et al. (2010)	HFA/AS = 61 males = 52	42.9 (10.7)	WAIS = 112.4 (15.4)	FPT	-0.76 [-1.20, -0.32]
	HC = 32	38.7 (9.3)	WAIS = 115.9 (10.0)	SST	-0.26 [-0.69, 0.17]

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
	males = 24				
Torralva et al. (2013)	AS = 25 males = 72%	33.9 (11.1)	NR	RMET	-0.37 [-0.89, 0.14]
				FPT	-1.44 [-2.01, -0.87]
	HC = 36 males = 60%	36.4 (9.9)	NR		
White et al. (2011)	ASD = 16 males = 12	33.0 (10.3)	WAIS: Verbal = 111.3 (12.7) WAIS: Performance = 106.4 (12.8)	FBT	-0.81 [-1.54, -0.08]
				SST	-1.16 [-1.92, -0.40]
	HC = 15	36.5 (9.9)	WAIS: Verbal = 114.1 (12.0)		

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
	males = 11		WAIS: Performance = 110.5 (13.7)	SHA	-1.06 [-1.45, -0.67]
White et al. (2014)	ASD = 22 males = 19 HC = 11 males = 10	13.5 14.3	WISC: Verbal = 110.5 WISC: Performance = 99.0 WISC: Verbal = 118.0 WISC: Performance = 103.0	FBT	-0.83 [-1.58, -0.07]
Wilson et al. (2014)	ASD = 89 males = 89 HC = 89 males = 89	26.0 (7.0) 28.0 (6.0)	Verbal IQ = 110.0 (14.0) Verbal IQ = 109.0 (13.0)	RMET	-0.98 [-1.29, -0.67]
				FBT	0.09 [-0.21, 0.38]
				SHA	-0.72 [-1.39, -0.06]

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
Zalla et al. (2009)	AS = 15 males = NR HC = 15 males = NR	28.0 (7.0) 27.8 (4.5)	WAIS-III = 114.8 (16.7) WAIS-III = 115.3 (14.6)	FPT	-1.71 [-2.55, -0.88]
Zalla and Leboyer (2011)	HFA = 20 males = 16 HC = 28 males = 21	27.6 (6.7) 27.9 (7.6)	WAIS = 93.5 (22.4) WAIS = 97.7 (12.9)	FPT	-0.69 [-1.28, -0.10]
Zalla et al. (2015)	HFA/AS = 19 males = 16	28.8 (7.1)	WAIS-III = 96.3 (19.8)	FPT	-1.36 [-2.07, -0.66]

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
	HC = 19 males = 15	26.4 (6.1)	WAIS-III = 101.2 (7.5)		
Zalla et al. (2016)	ASD = 21 males = NR HC = 21 males = NR	35.4 (14.5) 31.4 (13.6)	Full IQ = 101.7 (18.8) Full IQ = 102.8 (14.3)	FPT	-0.96 [-1.59, -0.32]
Yeh et al. (2010)	HFA/AS = 32 males = 22 HC = 34 males = 23	13.1 (2.4) 12.8 (0.7)	WISC = 94.7 (11.8) WISC = 93.4 (7.6)	FBT	-0.75 [-1.24, -0.25]
				FPT	-0.96 [-1.46, -0.44]
				SST	-0.76 [-1.26, -0.26]

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
Adenzato et al. (2012)	AN = 30 males = 0 BMI = 15.1 (1.7) HC = 32 males = 0 BMI = 20.5 (2.7)	19.73 (6.0) 20.2 (1.5)	NR NR	RMET	-0.37 [-0.87, 0.13]
Bentz et al. (2017a)	AN = 28 males = 0 BMI = 16.6 (1.2) HC = 41 males = 0 BMI = 22.0 (2.6)	16.1 (1.5) 17.7 (2.2)	RIAS = 107.7 (10.5) RIAS = 107.3 (9.5)	RMET	0.42 [-0.06, 0.91]
				SHA	0.10 [-0.38, 0.58]
				TASIT	0.14 [-0.29, 0.57]

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
	AN-REC = 43 males = 0 BMI = 21.3 (1.8)	18.4 (1.6)	RIAS = 102.8 (11.5)	RMET	
	HC = 41 males = 0 BMI = 22.0 (2.6)	17.7 (2.2)	RIAS = 107.3 (9.5)	SHA	-0.05 [-0.48, 0.38]
				TASIT	-0.30 [-0.78, 0.18]
Brockmeyer et al. (2016)	AN = 25 males = 0 BMI = 15.3 (1.2)	23.7 (5.6)	NR	MASC – emotions	-0.63 [-1.19, -0.06]
	HC = 25 males = 0 BMI = 21.8 (1.8)	24.6 (2.3)	NR	MASC – total	-0.40 [-0.96, 0.16]

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
Calvo Sagardoy et al. (2014)	AN (adolescent) = 21 males = NR BMI = 17.3 (11.2) HC (adolescent) = 28 males = NR BMI = 21.8 (17.9)	14 – 18 14 – 18	NR NR	RMET	-0.21 [-0.78, 0.36]
	AN (adult) = 27 males = NR BMI = 17.3 (11.2) HC (adult) = 13 males = NR	19 – 50 19 – 50	NR NR	RMET	-0.61 [-1.29, 0.06]

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
	BMI = 21.8 (17.9)				
Gal et al. (2011)	AN = 20 males = NR BMI = 16.5 (2.3)	15.5 (2.0)	NR	FPT	-0.61 [-1.24, 0.03]
	HC = 20 males = NR BMI = 20.0 (2.9)	15.4 (2.0)	NR	FBT	-0.52 [-1.15, 0.11]
Gillberg et al. (2010)	AN-WR = 42 males = NR BMI = 22.4 (4.6)	32	WAIS-III = 99.4 (14.3)	SHA	-0.46 [-0.89, -0.04]
	HC = 46 males = 0	32	WAIS-III = 104.1 (11.1)		

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
	BMI = 23.4 (4.2)				
Harrison et al. (2009)	AN = 20 males = 0 BMI = 15. 8 (1.2) HC = 20 males = 0 BMI = 21.8 (1.6)	26.3 (5.7) 28.4 (8.5)	NART = 114.5 (4.6) NART = 114.9 (5.8)	RMET	-1.18 [-1.85, -0.51]
Harrison et al. (2010b)	AN = 48 males = 0 BMI = 15.4 (1.8) HC = 48	26.7 (9.8) 28.5 (9.9)	NART = 11.4 (8.6) NART = 113.3 (7.4)	RMET	-0.51 [-0.87, -0.15]

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
	males = 0 BMI = 21.6 (1.9)				
Jermakow and Brzezicka (2016)	AN = 10 males = 0 BMI = 14 – 22 HC = 33 males = 0 BMI = NR	26.8 (4.3) 21.3 (1.4)	NR NR	RMET	0.49 [-0.20, 1.18]
Kanakam et al. (2013)	AN = 24 males = 0 BMI = NR	NR	NR	RMET	-0.32 [-0.82, 0.19]

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
	HC = 42 males = 0 BMI = NR	NR	NR		
Kucharska et al. (2016)	AN = 25 males = 0 BMI = 17.6 (2.2) HC = 25 males = 0 BMI = 23.4 (3.6)	27.1 (6.3) 24.5 (5.2)	NR NR	RMET	-0.21 [-0.77, 0.34]
Laghi et al. (2015)	AN = 40 males = 0 BMI = 15.8 (1.5)	14.9 (1.4)	NR	RMET	0.15 [-0.29, 0.59]

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
	HC = 40 males = 0 BMI = 21.9 (2.6)	14.9 (0.6)	NR		
Leppanen et al. (2017a)	AN = 30 males = 0 BMI = 16.3 (3.0) HC = 29 males = 0 BMI = 23.2 (3.7)	26.2 (6.8) 26.8 (8.5)	Not measured Not measured	RMET	0.58 [0.06, 1.10]
Medina-Pradas et al. (2012)	AN = 44 males = 0	26.8 (9.9)	NR	RMET	-0.75 [-1.20, -0.31]

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
	BMI = 15. 8 (1.7)				
	HC = 39 males = 0 BMI = 21.3 (2.1)	26.0 (14.7)	NR		
Oldershaw et al. (2010)	AN = 40 males = 3 BMI = 16.6 (1.3)	27.3 (10.0)	NART = 107.5 (11.2)	RMET	-0.53 [-1.00, -0.06]
				RMVT	-0.73 [-1.20, -0.25)
	HC = 47 males = 10 BMI = 23.0 (2.8)	29.8 (8.0)	NART = 112.5 (7.9)	RMFT	-0.74 [-1.22, -0.27]
				LEAS	-0.36 [-0.82, 0.11]

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
Postorino et al. (2017)	AN = 30 males = 0 BMI = NR HC = 30 males = 0 BMI = NR	14.2 (1.6) 13.6 (1.6)	Full IQ = 105.0 (15.0) Full IQ = 106.0 (13.0)	NEPSY-II	-0.67 [-1.19, -0.15]
Rommel et al. (2013)	AN = 25 males = 0 BMI = 14.8 (1.7) HC = 37 males = 0	19.9 (3.1) 20.5 (3.0)	NR NR	LEAS	-0.22 [-0.73, 0.29]

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
	BMI = 20.4 (2.5)				
Rothschild-Yakar et al. (2010)	AN = 34 males = 0 BMI = 16.5 (2.4) HC = 35 males = 0 BMI = 20.1 (2.1)	18.2 (2.7) 17.8 (2.3)	NR NR	SCORS	-1.14 [-1.65, -0.63]
Russell et al. (2009)	AN = 22 males = 0 BMI = 15.3 (1.2) HC = 20	26.7 (4.8) 30.3 (6.5)	NART = 118.3 (3.0) NART = 119.2 (2.1)	Cartoons	-1.94 [-2.67, -1.21]
				RMET	-1.34 [-2.01, -0.67]

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
	males = 0 BMI = 16.2 (2.0)				
Tapajoz Pereira De Sampaio et al. (2013b)	AN = 24 males = 0 BMI = 18.1 (1.8)	24.5 (7.6)	Full IQ = 102.5 (19.8)	RMET	-1.14 [-1.75, -0.53]
	HC = 24 males = 0 BMI = 21.5 (1.8)	25.2 (6.9)	Full IQ = 100.2 (15.2)	FPT	-0.81 [-1.40, -0.22]
Tapajoz Pereira De Sampaio et al. (2013a)	AN = 22 males = 0 BMI = 18.1 (2.8)	24.3 (7.6)	Word Accentuation Test = 101.4 (20.4)	RMET	-1.21 [-1.83, -0.58]

Study	Group N; N males (BMI)	Age	IQ	Task	SMD [95% CI]
	HC = 24 males = 0 BMI = 21.5 (1.8)	25.2 (6.9)	Word Accentuation Test = 100.2 (15.2)	FPT	-0.72 [-1.32, -0.13]
Tchanturia et al. (2004)	AN = 20 males = 0 BMI = 15.8 (2.2)	27.4 (7.9)	NR	Stories (similar to SST)	-0.68 [-1.32, -0.04]
	HC = 20 males = 0 BMI = 21.5 (1.5)	28.3 (7.4)	NR	Cartoons	-0.58 [-1.22, 0.05]

ASD = autism spectrum disorder; AS = Asperger's Disorder; HFA = high functioning autism; AN = anorexia nervosa; EDNOS = Eating Disorder Not Otherwise Specified; AN-REC = Recovered from anorexia nervosa; AN-WR = Weight restored people with anorexia nervosa; F = female; M = male; AoE = Arena of Emotions; A-ToM = Animated Theory of Mind test; C-ToM = Computerised Theory of Mind test; MASC – Emotions = Emotions category of the Movie for the Assessment of Social Cognition; RMET = Reading the Mind in the Eyes Test; RMFT = Reading the Mind in the Film Test; RMVT = Reading the Mind in the Voice Test; Levels of Emotional Awareness Scale; AMT = Awkward Moments Test; A-ToM = Animated Theory of Mind test; DST = Dewey Story Test; FBT = False Belief Test; FPT = Faux Pas Test; ToM Scale = Theory of Mind Scale; NEPSY-II = A Developmental NEuroPSYchological Assessment second edition; MASC = Movie for the Assessment of Social Cognition; PIS = Pragmatic Interpretation Stories; SST = Strange Stories Test; SCORS = Social Cognition and Object Relation; TASIT = The Awareness of Social Inference Test; PIT = Projective Imagination Test; SAT = Social attribution Test; SHA = Smith-Happé Animations; TAT = Thematic Apperception Test; IQ = intelligence quotient; WAIS(-R) = Wechsler Adult Intelligence Scale (revised); FSIQ = Full Scale Intelligence Quotient; NART = National Adult Reading Test; WISC = Wechsler Intelligence Scale for Children; WASI = Wechsler Abbreviated Scale of Intelligence; TIQ = Total Intelligence Quotient; VIQ = Verbal Intelligence Quotient; Performance Intelligence Quotient; MWIT = Mehrfachwahl-Wortschatz-Intelligenz test; WAT = Word accentuation test; RIAS = Reynolds Intellectual Assessment Scales; NR = not reported.

4.2 Study quality assessment

The study quality assessment results are shown in Supplementary Table 1. Interrater reliability was acceptable (88.2 %) and no study met the criteria for exclusion. Only ten studies provided some sample size justification, indicating that majority of the studies may have been inadequately powered.

4.3 Emotional theory of mind

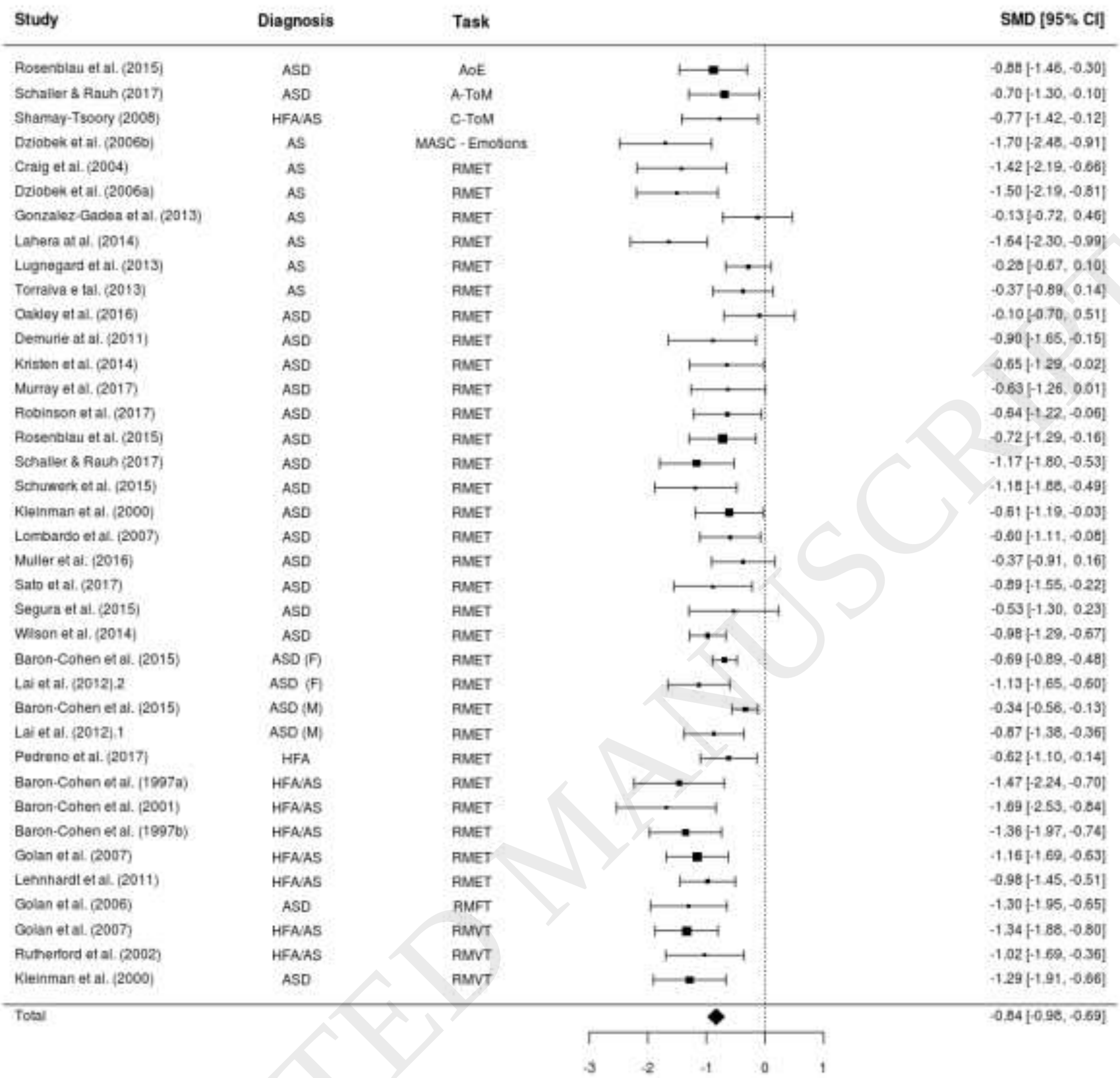
The standardised residuals and Cook's distance of each study included in the meta-analysis are presented in Supplementary Table 2 and Supplementary Figure 1 respectively. The Z scores of the standardised residuals of three studies (Bentz et al., 2017a; Jermakow and Brzezicka, 2016; Leppanen et al., 2017a) exceeded 1.96, but the corresponding Cook's distance values were less than 0.11 and did not exceed the cut off. Therefore, the studies were not deemed to be influential outliers and were included in the meta-analysis.

The differences between healthy individuals and those with ASD and AN in performance on the emotional theory of mind tasks are presented in Figure 2 and 3, respectively. Due to the large number of studies, the results are presented in two figures to allow for better visualisation. The meta-analysis revealed that relative to the HCs, the AN/ASD groups performed significantly worse with a medium effect size ($g = -0.69$, $z = -9.60$, $p < 0.0001$, 95% CI [-0.83, -0.55]). When the two diagnostic groups were inspected separately there was a significant difference between people with ASD and the HCs with a large effect size ($g = -0.84$, $z = -11.61$, $p < 0.0001$, 95% CI [-0.98, -0.69]) and a small, significant difference between people with AN and the HCs ($g = -0.41$, $z = -3.09$, $p = 0.002$, 95% CI [-0.67, -0.15]).

There was also significant between-study heterogeneity ($I^2 = 76.23\%$, $Q = 184.07$, $p < 0.0001$), which was explored further with a meta-regression. The meta-regression did not explain a significant portion of the heterogeneity ($Q_{moderators} = 16.58$, $p = 0.121$), leaving significant, unexplained residual heterogeneity ($Q_{residual} = 52.41$, $p = 0.002$). The final model was formed of the following moderators: the diagnostic group (Z = -0.33, p = 0.739, 95% CI [-0.86,0.61], the percentage of males in the sample (Z = -0.01, p = 0.994, 95% CI [-0.83, 0.82]), age (Z = -0.98, p = 0.329, 95% CI [-0.05, 0.02]), the IQ of the patient group (Z = -0.48, p = 0.635, 95% CI [-0.05, 0.03]), the A-ToM task (Z = 1.33, p = 0.183, 95% CI [-0.22, 1.18]), the LEAS (Z = 0.97, p = 0.330, 95% CI [-0.30, 0.89]), the emotions subscale of the MASC (Z = -0.62, p = 0.535, 95% CI [-1.61, 0.89]), the RMET (Z = 0.44, p = 0.662, 95% CI [-0.37, 0.58]), the RMFT (Z = -0.34, p = 0.736, 95% CI [-0.69, 0.49]), the RMVT (Z = -0.31, p = 0.754, 95% CI [-0.64, 0.46]), and the quality assessment score (Z = -0.67, p = 0.506, 95% CI [-3.52, 1.74]).

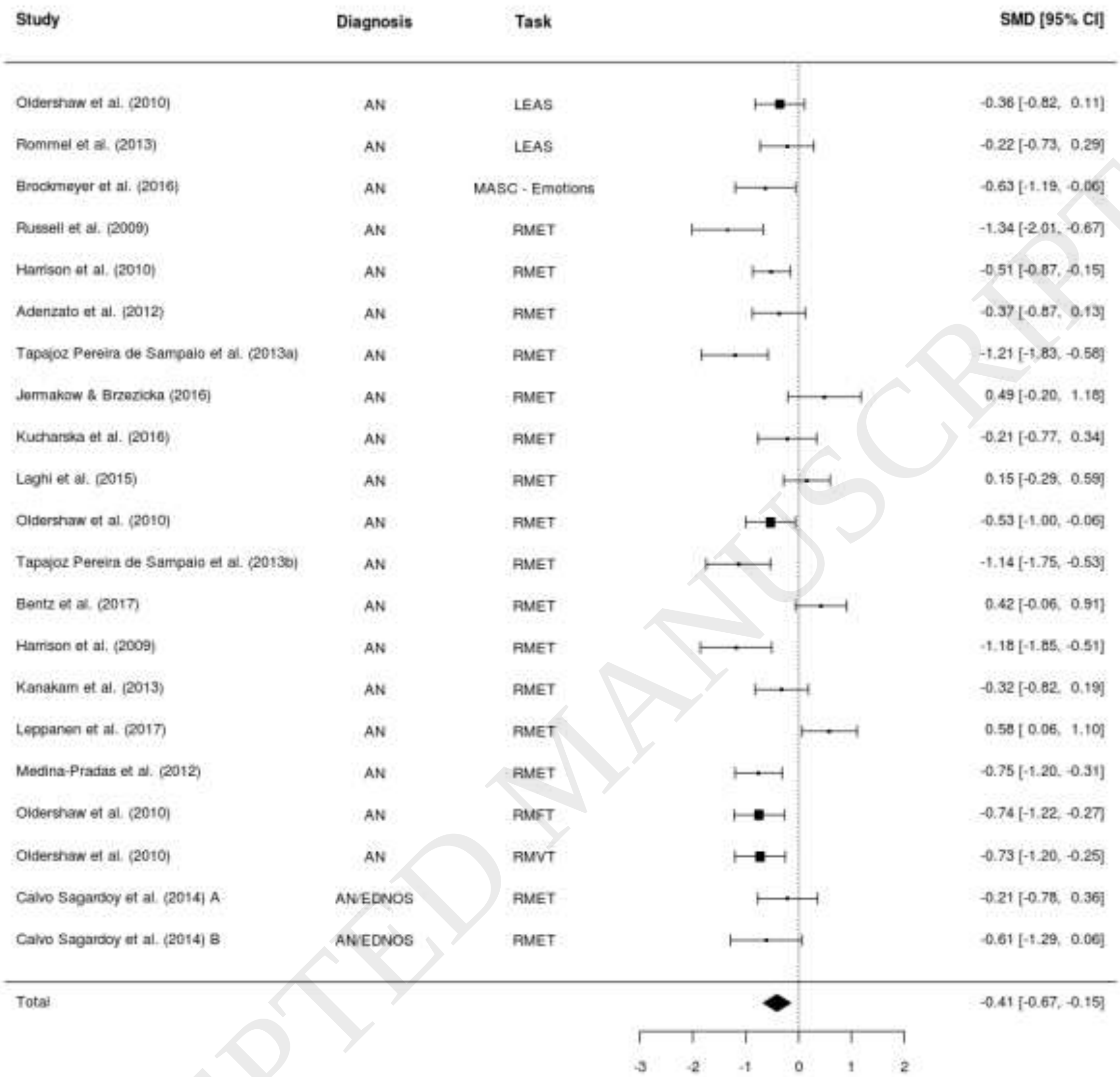
Begg's rank correlation test of funnel plot asymmetry suggested there was significant publication bias present ($\tau = -0.32$, $p = 0.0003$; Supplementary Figure 2).

Figure 2. Emotional theory of mind in ASD.



ASD = autism spectrum disorder; AS = Asperger's Disorder; HFA = high functioning autism; F = female; M = male; AoE = Arena of Emotions; A-ToM = Animated Theory of Mind test; C-ToM = Computerised Theory of Mind test; MASC – Emotions = Emotions category of the Movie for the Assessment of Social Cognition; RMET = Reading the Mind in the Eyes Test; RMFT = Reading the Mind in the Film Test; RMVT = Reading the Mind in the Voice Test; SMD = standardised mean difference; CI = Confidence interval.

Figure 3. Emotional theory of mind in AN.



AN = anorexia nervosa; EDNOS = Eating Disorder Not Otherwise Specified; Levels of Emotional Awareness Scale; MASC – Emotions = Emotions category of the Movie for the Assessment of Social Cognition; RMET = Reading the Mind in the Eyes Test; RMFT = Reading the Mind in the Film Test; RMVT = Reading the Mind in the Voice Test; SMD = standardised mean difference; CI = Confidence interval. Calvo Sagardoy et al. (2014) A = adolescent participants; Calvo Sagardoy et al. (2014) B = adult participants.

4.4 Understanding of simple social interactions

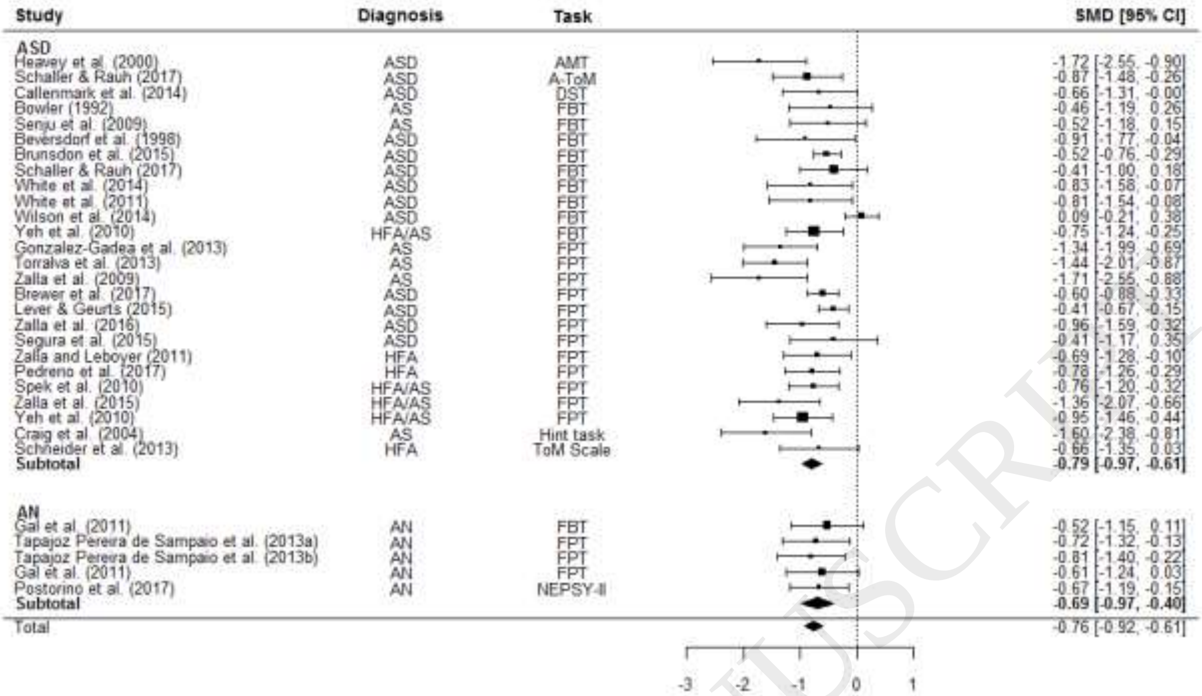
The standardised residuals and Cook's distance of each study are presented in Supplementary Table 3 and Supplementary Figure 3 respectively. The Z score of a standardised residual of one study (Wilson et al., 2014) exceeded 1.96, but the Cook's distance of the study was 0.07 and did not exceed 1. Therefore, the study was not deemed to be an influential outlier and was not removed from analysis.

The differences between healthy individuals, autistic people and people with AN in understanding of simple social interactions are presented in Figure 4. The meta-analysis showed that the AN/ASD groups performed significantly worse the HCs with a medium effect sizes ($g = -0.76$, $z = -9.63$, $p < 0.0001$, 95% CI [-0.92, -0.61]). Both the ASD and AN group performed more poorly than the HCs with moderate effect sizes (ASD: $g = -0.79$, $z = -8.52$, $p < 0.0001$, 95% CI [-0.97, -0.61]; AN: $g = -0.69$, $z = -4.75$, $p < 0.0001$, 95% CI [-0.97, -0.40]).

The meta-analysis also revealed significant between-study heterogeneity ($I^2 = 65.56\%$, $Q = 70.51$, $p < 0.0001$), which was explored further with a meta-regression. The meta-regression explained a significant portion of the between-study heterogeneity ($Q_{moderator} = 44.92$, $p < 0.0001$), leaving no significant residual heterogeneity ($Q_{residual} = 4.29$, $p = 0.933$). The final model was formed of the following moderators: the diagnostic group ($Z = -2.22$, $p = 0.027$, 95% CI [-1.94, -0.12]), the percentage of males in the sample ($Z = 2.30$, $p = 0.022$, 95% CI [0.17, 2.12], age ($Z = 0.64$, $p = 0.524$, 95% CI [-0.01, 0.01]), the IQ of the diagnostic group ($Z = -0.64$, p = 0.520, 95% CI [-0.04, 0.02]), the AMT (Z = -1.75, p = 0.080, 95% CI [-1.98, 0.11]), the Hint task (Z = -1.02, p = 0.306, 95% CI [-1.43, 0.45]), the NEPSY-II (Z = 0.87, p = 0.383, 95% CI [-0.48, 1.25]), and the ToM Scale (Z = 1.05, p = 0.293, 95% CI [-0.42, 1.38]), the FBT (Z = 1.74, p = 0.082, 95% CI [-0.05, 0.91]), the FPT (Z = 0.70, p = 0.486, 95% CI [-0.35, 0.74]), and the quality assessment score (Z = 3.35, p = 0.001, 95% CI [1.44, 5.50]). The effect appeared to be largely driven by the percentage of males in the sample, diagnostic group, and by the quality assessment scores. Studies with autistic participants, fewer males, and lower quality assessment scores appeared to show the largest differences between the diagnostic and control groups. However, since there were fewer studies that included AN participants or primarily females, and the variance in the quality assessment scores was very small, this finding should be interpreted with caution.

Begg's rank correlation test for funnel plot asymmetry indicated that significant publication bias was present (τ = -0.26, p = 0.041; Supplementary Figure 4).

Figure 4. Understanding of simple social interactions in ASD and AN.



ASD = autism spectrum disorder; AS = Asperger's Disorder; HFA = high functioning autism; AN = anorexia nervosa; AMT = Awkward Moments Test; A-ToM = Animated Theory of Mind test; DST = Dewey Story Test; FBT = False Belief Test; FPT = Faux Pas Test; ToM Scale = Theory of Mind Scale; NEPSY-II = A Developmental NEuroPSYchological Assessment second edition; SMD = standardised mean difference; CI = Confidence interval.

4.5 Understanding of complex social interactions

The standardised residuals and Cook's distance of each study are presented in Supplementary Table 4 and Supplementary Figure 5 respectively. The Z scores of standardised residuals of four studies (Bentz et al., 2017a; Dziobek et al., 2006a; Dziobek et al., 2006b; Martinez et al., 2017) exceeded 1.96, but the Cook's distance values of the two studies were less than 0.27

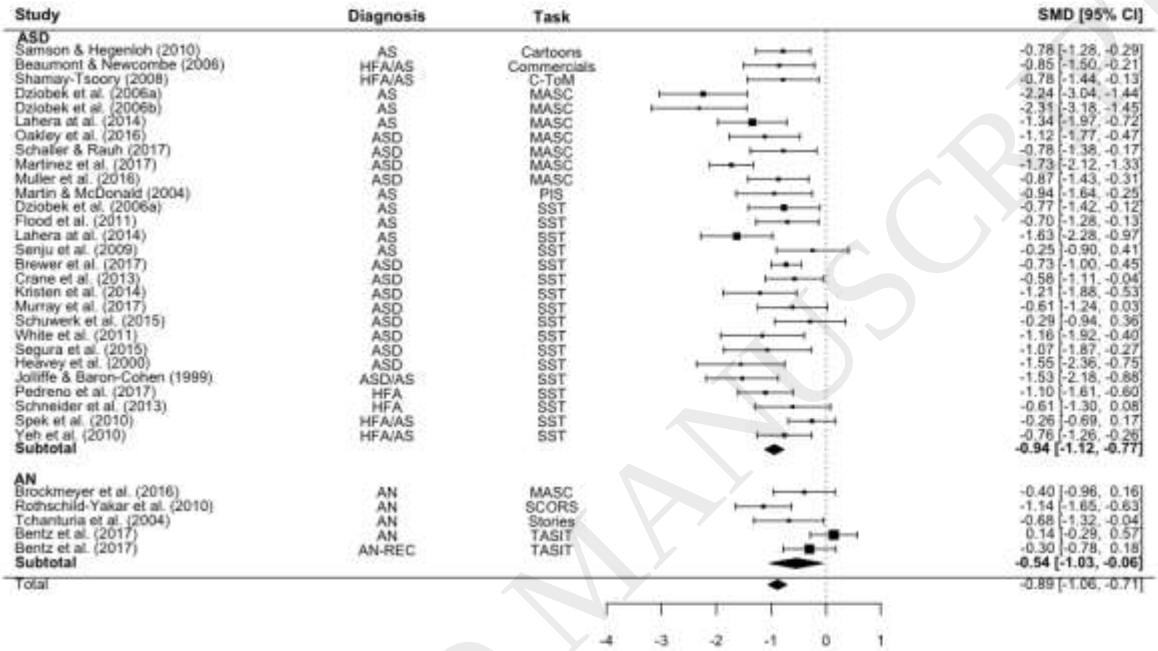
and did not exceed 1. Thus, these studies were not deemed to be influential outliers and were not excluded from analysis.

The differences between healthy individuals, and autistic people and people with AN in understanding of complex social interactions are presented in Figure 5. Overall, the AN/ASD groups were significantly poorer in comprehending complex social interaction than the healthy individuals with a large effect size ($g = -0.89$, $z = -10.12$, $p < 0.0001$, 95% CI [-1.06, -0.71]). When inspected separately, the ASD and AN groups performed poorer than healthy individuals with a large and medium effect sizes, respectively (ASD: $g = -0.94$, $z = -10.55$, $p < 0.0001$, 95% CI [-1.12, -0.77; AN: $g = -0.54$, $z = -2.18$, $p = 0.029$, 95% CI [-1.03, -0.06]).

There was significant between-study heterogeneity ($I^2 = 67.14\%$, $Q = 105.57$, $p < 0.0001$), which was explored further. The meta-regression significantly explained a portion of the heterogeneity ($Q_{moderator} = 19.13$, $p = 0.004$), but there was still significant residual heterogeneity ($Q_{residual} = 40.14$, $p = 0.0002$). The final model consisted of the following moderators: the percentage of males in the sample ($Z = -0.79$, $p = 0.427$, 95% CI [-2.62, 1.11]), age ($Z = -1.65$, $p = 0.099$, 95% CI [-0.08, 0.01]), the IQ of the patient group ($Z = 1.33$, $p = 0.184$, 95% CI [-0.02, 0.09]), the Commercials task ($Z = -0.33$, $p = 0.742$, 95% CI [-1.27, 0.90]), the MASC task ($Z = -4.15$, $p < 0.0001$, 95% CI [-1.45, -0.52]), and the quality assessment score ($Z = 0.21$, $p = 0.833$, 95% CI [-4.39, 5.45]). The moderator affect appeared to be largely driven by the MASC task, the studies that used this task showed the largest differences between the diagnostic and control groups.

Begg's rank correlation test of funnel plot asymmetry showed significant evidence of publication bias (τ = -0.33, p = 0.006; Supplementary Figure 6).

Figure 5. Understanding of complex social interactions in ASD and AN.



ASD = autism spectrum disorder; AS = Asperger's Disorder; HFA = high functioning autism; AN = anorexia nervosa; AN-REC = Recovered from anorexia nervosa; C-ToM = Computerised Theory of Mind test; MASC = Movie for the Assessment of Social Cognition; PIS = Pragmatic Interpretation Stories; SST = Strange Stories Test; SCORS = Social Cognition and Object Relation; TASIT = The Awareness of Social Inference Test; SMD = standardised mean difference; CI = Confidence interval.

4.6 Implicit social attribution

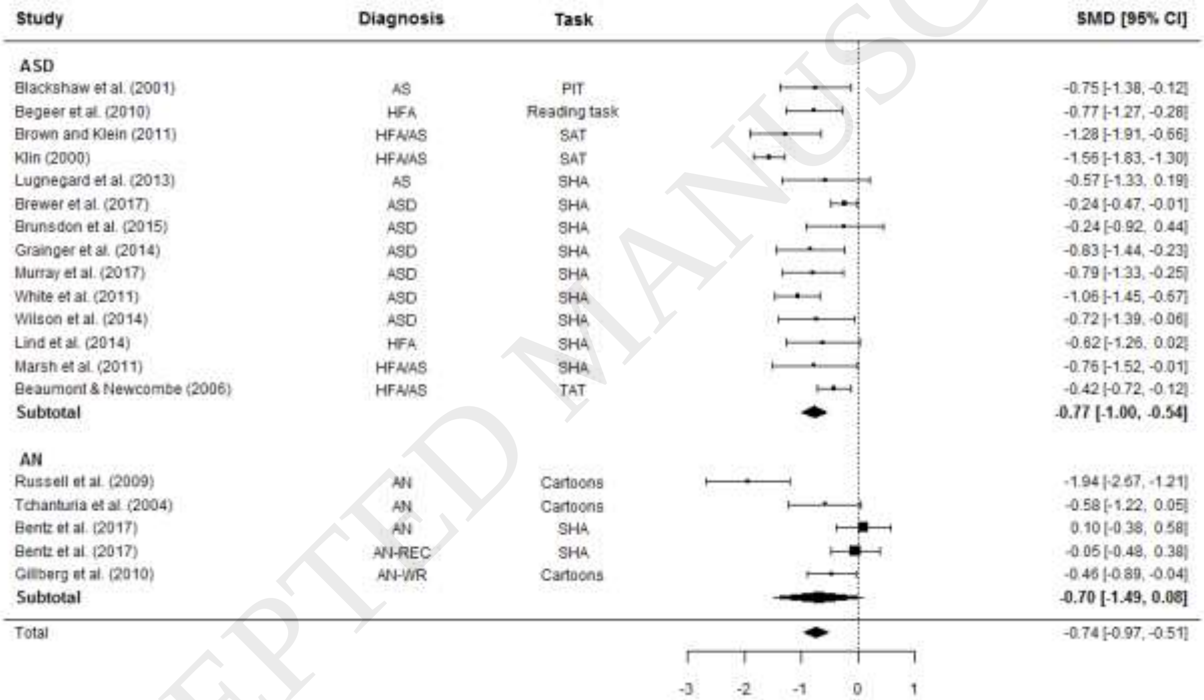
The standardised residuals and Cook's distance of each study is presented in Supplementary Table 5 and Supplementary Figure 7, respectively. The Z score of the standardised residual of one study (Russell et al., 2009) exceeded 1.96, but the Cook's distance was 0.23 and did not exceed 1. Therefore, the study was not deemed an influential outlier and was not removed from further analysis.

The differences between healthy individuals, and autistic people and people with AN in implicit social attribution are presented in Figure 6. Overall, the AN/ASD groups performed more poorly on the tasks than the healthy individuals with a medium effect size ($g = -0.74$, $z = -6.33$, $p < 0.0001$, 95% CI [-0.97, -0.51]). When the groups were inspected separately, both performed more poorly than the HCs in the social attribution tasks with large and medium effect sizes (ASD: $g = -0.80$, $z = -6.47$, $p < 0.0001$, 95% CI [-1.00, -0.54]; AN: $g = -0.70$, $z = -1.75$, $p = 0.080$, 95% CI [-1.49, 0.08]). However, the difference between people with AN and HCs did not reach significance.

There was significant between-study heterogeneity ($I^2 = 79.28$, $Q = 92.81$, $p < 0.0001$), which was explored further. The meta-regression did not explain a significant portion of the heterogeneity ($Q_{moderator} = 14.99$, $p = 0.091$), but left no significant residual heterogeneity ($Q_{residuals} = 3.96$, $p = 0.138$). The final model consisted of the following moderators: the diagnostic group ($Z = 0.40$, $p = 0.690$, 95% CI [-3.74, 5.64]), the percentage of males ($Z = -0.83$, $p = 0.406$, 95% CI [-3.12, 1.26]), age ($Z = -0.76$, $p = 0.449$, 95% CI [-0.22, 0.10]), the IQ of the patient group ($Z = -0.16$, $p = 0.877$, 95% CI [-0.08, 0.07]), the PIT ($Z = 0.16$, $p = 0.870$, 95% CI [-4.77, 5.64]), the Reading task ($Z = 0.08$, $p = 0.933$, 95% CI [-5.32, 5.79]), the SHA task ($Z = 0.79$, p = 0.431, 95% CI [-1.80, 4.22]), the TAT (Z = 0.66, p = 0.509, 95% CI [-2.57, 5.19]), and the quality assessment score (Z = -0.18, p = 0.859, 95% CI [-7.70, 6.42])..

Begg's rank correlation test did not reveal evidence of significant publication bias (τ = -0.08, p = 0.679; Supplementary Figure 8).

Figure 6. Implicit social attribution in ASD and AN.



ASD = autism spectrum disorder; AS = Asperger's Disorder; HFA = high functioning autism; AN = anorexia nervosa; AN-REC = Recovered from anorexia nervosa; AN-WR = Weight restored people with anorexia nervosa; PIT = Projective Imagination Test; SAT = Social attribution Test; SHA = Smith-Happé Animations; TAT = Thematic Apperception Test; SMD = standardised mean difference; CI = Confidence interval.

5 Discussion

The aim of the present review was to examine the theory of mind profile in autistic people as well as in people with AN. The majority of the available studies included autistic individuals, and it became clear that areas other than emotional theory of mind have been relatively under-researched in AN. The meta-analyses showed that autistic people and people with AN have similar theory of mind profiles. Although both diagnostic groups performed more poorly in the theory of mind tasks than HC individuals, autistic people appeared to have more difficulties than those with AN. This finding suggests that there are a number of similarities between autistic people and people with AN in social cognition, but there may also be some differences that warrant further investigation.

The effect size estimates suggested that there may be some differences between people with AN and autistic people in emotional theory of mind even though the diagnostic group did not emerge as a significant moderator of between-study heterogeneity. People with AN showed significant difficulties in emotional theory of mind relative to healthy individuals, but these difficulties appeared to be less severe compared to autistic people. This finding is in line with a recent suggestion that people with AN may have greater difficulties with implicit responses to emotional cues, including response and interpretation biases, rather than in explicit labelling (Adenzato et al., 2012; Cardi et al., 2013; Cardi et al., 2017; Davies et al., 2016; Harrison et al., 2011; Harrison et al., 2010a; Leppanen et al., 2017b; Mendlewicz et al., 2005). Indeed, a recent experimental study reported that although people with AN had some difficulties in recognising disgust, this may have been driven by a bias towards interpreting this facial affect as anger (Dapelo et al., 2016). Conversely, a recent meta-analytic review documented that autistic people display difficulties in recognition of basic emotions with small to large effect sizes (Uljarevic and Hamilton, 2013). Moreover, experimental work has demonstrated that even after correcting for response biases, autistic people show general difficulties in the explicit detection of emotions (Evers et al., 2015). Taken together, these findings suggest that people with AN and autistic people may have different difficulties in processing and responding to emotional cues.

People with AN and autistic individuals showed similar performance on measures of understanding simple and complex social interactions as well as in implicit social attribution, even though the AN group did not do significantly worse on social attribution than the HCs. The present findings are supported by previous work showing that both people with AN and autistic people report elevated social anhedonia and have similar neuropsychological processing profiles (Chevallier et al., 2012a; Chevallier et al., 2012b; Harrison et al., 2014; Tchanturia et al., 2012; Westwood et al., 2017b). Further support comes from the notion that these processes could be influenced by participants' understanding of the implicit social rules that guide behaviour in social situations (Baez et al., 2012; Jameel et al., 2015; Kipps and Hodges, 2006; Zalla et al., 2009). Interestingly, previous work has documented that autistic people have a good understanding of explicit social rules, but struggle when rules are abstract or implicit, or when the spontaneous application of existing rules is needed (Baez et al., 2012; Myles et al., 2001). Similarly, there has been some suggestion that although semantic understanding of social rules may be intact in AN, when these rules are embedded into social scenarios the picture becomes complex and people with AN have difficulties detecting when rules are broken (Bentz et al., 2017b). Taken together, these findings suggest that spontaneous application of social rules to abstract stimuli may be similarly affected in AN and ASD.

It is of interest that people with AN appeared to have somewhat less severe difficulties in both understanding of social interactions, relative to autistic people. Although this finding could be driven by the relative paucity of research examining these processes in people with AN, it could also indicate that there may be differences in the underlying processes between these two groups and further research is needed. Indeed, recent behavioural findings suggest that people with AN do not show difficulties in abstract thinking in general, including understanding or explaining the meaning of non-literal abstract concepts and proverbs (Bentz et al., 2017b). It seems that people with AN have difficulties understanding non-literal communication specifically when it appears in a social context (Rothschild-Yakar et al., 2010; Tchanturia et al., 2004). Conversely, difficulties with understanding abstract, non-literal concepts, such as metaphors and proverbs, is a recognised feature of ASD regardless of context and is likely related to more general difficulties in language processing (Boucher, 2012; Ganz and Flores, 2009; Olofson et al., 2014; Tager-Flusberg and Caronna, 2007). Taken together, it may be that people with AN and autistic people have differential difficulties in understanding non-literal social interactions and implicit attribution of social understanding. However, further research, particularly studies examining these processes in AN, is still needed before firm conclusions can be drawn.

6 Limitations and future directions

The main limitation of the present review is that we were not able to directly compare performance on theory of mind tasks between autistic individuals and people with AN due to a lack of studies. Instead, the two groups were compared by first calculating SMD comparing the AN/ASD group against a HC group, and then conducting a meta-regression. This sets some limits on the conclusions that can be drawn from this review as it is difficult to detect any subtle differences in theory of mind performance between the two diagnostic group through this method. Thus, the present findings highlights the need for further research to examine the theory of mind profiles in these related disorders, particularly in the light of the subtle differences observed in the effect size estimated between the two group in emotional theory of mind and understanding of simple social interactions. Further research into similarities and potential differences in the theory of mind profiles between people with AN and autistic individuals could help to further the understanding of the underlying aetiology in both disorders.

Another limitation is that there were substantially fewer studies investigating theory of mind, especially understanding of social interactions and social attribution, in people with AN. This shows that theory of mind is a relatively under-researched area compared to work focusing on eating related behaviours, which has been the traditional focus in the eating disorder literature. The present review shows that further research into theory of mind in AN is warranted, especially in the light of theoretical models that highlight the role of social cognition in the development and maintenance of disordered eating (Treasure and Schmidt, 2013). This means that when diagnostic group was entered as a moderator in the meta-regressions the number of studies that included autistic people and those that included people with AN were not balanced. Such unbalances could have influenced the results of the present meta-regressions could have impacted the results. Therefore, further research with more complex tasks is still needed to provide a clear picture of the theory of mind profile in AN.

The meta-analyses also revealed significant between-study heterogeneity, which could be partly explained by differences between the diagnostic groups, in the tasks used, in the average age of the sample, in the proportion of males in the sample, and in the IQ of the patient group. Some studies using specific tasks, such as the MASC, reported significantly greater differences between the diagnostic and control groups than other studies. Further examination of the subtle differences between the tasks may be of interest for future studies to establish whether there may be more fine grained differences in the aspects of theory of mind measured in these tasks. This also suggests that future studies may benefit from greater consistency in the tasks used, which would provide a clearer picture of the theory of mind profile in both ASD and AN.

Disentangling the impact of gender, age, and IQ on the between-study heterogeneity is more difficult. Although they contributed to a significant model, they did not individually significantly explain the heterogeneity. However, the present review does show that majority of the studies investigating theory of mind in autistic adolescents and adults included a large number of male participants with only few females. The studies that investigated theory of mind in people with AN, on the other hand, primarily included only female participants. Additionally, majority of the studies included in the present review recruited adults between the ages of 18 and 35. A few studies included adolescents under the age of 18 and no studies included older adults. Similarly, majority of the studies included participants with average or above average IQ. This gender, age, and IQ imbalance could be a potential source of between-study heterogeneity.

Interestingly, in three of the meta-analyses a combination of these factors at least partially explained the between-study heterogeneity, while in one of the meta-analyses we were unable to identify the source of the heterogeneity. Although we were unable to identify the source of the unexplained heterogeneity, it is possible that variability in the patient groups could have had an impact. Twelve studies reported that they included mixed groups of people with Asperger's syndrome, high-functioning ASD, and low-functioning ASD. Additionally, as starvation is believed to have substantial impact on social and cognitive functioning in AN (Keys et al., 1950), it is of importance to note that the majority of the studies in the present review included only underweight AN participants. Although two studies included AN participants who were weight restored or recovered, it is not possible to ascertain that theory of mind difficulties in AN are not at least partly due to the impact of malnutrition on the brain. Indeed, a systematic review of social-emotional processing in AN across illness stage reported that those recovered from AN had fewer difficulties in emotional awareness in self and others (Oldershaw et al., 2011). However, some difficulties, such as implicit attentional bias towards negative social cues, appeared to persist after recovery from AN (Oldershaw et al., 2011). Moreover, we were not able to examine the potential confounding impact of mood and anxiety on performance on the theory of mind tasks. This would be an important factor to examine further, particularly as people with AN and autistic individuals report significantly higher levels of depression and anxiety relative to the general population (Oldershaw et al., 2011). Additionally, people with mood and anxiety disorders show altered performance on a number of tasks assessing social-cognition, including theory of mind (Oldershaw et al., 2011). Future studies may benefit from further exploring the impact of these variables on theory of mind in ASD and AN.

In the meta-analysis that examined emotional theory of mind, majority of the studies used the RMET or a variation of the task. This task has recently been criticised for being an emotion recognition task rather than a theory of mind task (Oakley et al., 2016). This makes it difficult to determine if poorer performance in this task is due to difficulties in theory of mind or due difficulties such as alexithymia (Oakley et al., 2016). The RMET has also been criticised for using non-naturalistic, static images restricted to the eye region and for using multiple-choice format, which has been suggested to increase bias in the accuracy scores (Johnston et al., 2008). However, these criticisms are true of a number of other paradigms as well, such as the C-ToM. Therefore, although the studies that used the RMET did not emerge as significant moderators of between-study heterogeneity, future studies may benefit from using alternative, more ecologically valid tasks to assess emotional theory of mind.

Finally, all meta-analyses revealed significant publication bias according to Begg's test of funnel plot asymmetry. This is an important limitation of the present review as it suggests that many small studies reported larger effect sizes than larger studies. This can be an indication of inflated effect sizes in small studies, which would lead to bias in the pooled effect size estimates (Zhang et al., 2013). Therefore, more larger studies are needed to gain a clear picture of theory of mind profiles in both ASD and AN.

7 Conclusions

The present review examined the theory of mind profile in ASD and AN. The majority of the studies included autistic individuals indicating relative paucity of research in AN. Overall, autistic people and those with AN appeared to have similar difficulties in all aspects of theory of mind. However, there was some indication of potential group differences in emotional theory of mind. Autistic people showed greater difficulties in task performance and further investigation of potential differences between autistic people and individuals with AN would be of interest. These findings are supported by previous work demonstrating that there are similarities in certain aspects of social emotional and neurocognitive processing between individuals with AN and autistic people. Further research investigating the processes that underlie theory of mind difficulties in both AN and ASD would be of interest.

8 Acknowledgements

JL and FS are supported by MRC and MRF Child and young adult Mental health –the underpinning aetiology of self harm and eating disorders (ref: MR/R004595/1). KT is supported by MRC and MRF Child and young adult Mental health –the underpinning aetiology of self harm and eating disorders (ref: MR/R004595/1) and Swiss Anorexia Nervosa Foundation (ref: 58-16). JT receives salary support from the National Institute for Health Research (NIHR), Mental Health Biomedical Research at South London and Maudsley NHS Foundation Trust, and King's College London. The views expressed are those of the author(s) and not necessarily those of the NHS, the NIHR or the Department of Health.

The authors do not report any financial or non-financial conflicting interests.

9 References

Abell, F., Happé, F., Frith, U., 2000. Do triangles play tricks? Attribution of mental states to animated shapes in normal and abnormal development. Cognitive Development 15, 1-16.

Adenzato, M., Todisco, P., Ardito, R.B., 2012. Social Cognition in Anorexia Nervosa: Evidence of Preserved Theory of Mind and Impaired Emotional Functioning. PLOS ONE 7, e44414.

Ambwani, S., Berenson, K., Simms, L., Li, A., Corfield, F., Treasure, J., Obe, P., Frcp, F., 2016. Seeing Things Differently: An Experimental Investigation of Social Cognition and Interpersonal Behavior in Anorexia Nervosa. 49, 499-506.

American Psychiatric Association, 2013. Diagnostic and statistical manual of mental disorders (5th ed.). Author, Washington, DC.

Baez, S., Rattazzi, A., Gonzalez-Gadea, M.L., Torralva, T., Vigliecca, N.S., Decety, J., Manes, F., Ibanez, A., 2012. Integrating intention and context: Assessing social cognition in adults with asperger syndrome running title: Contextual social cognition in adults with AS. Frontiers in Human Neuroscience, 1-30.

Bal, E., Harden, E., Lamb, D., Van Hecke, A.V., Denver, J.W., Porges, S.W., 2010. Emotion Recognition in Children with Autism Spectrum Disorders: Relations to Eye Gaze and Autonomic State. Journal of Autism and Developmental Disorders 40, 358-370.

Baron Cohen, S., 1985. Social cognition and pretend plain in autism, Unpublished doctoral dissertation, Universtiy of London.

Baron-Cohen, S., 1989. The autistic child's theory of mind: a case of specific developmental delay. Journal of Child Psychology and Psychiatry 30, 285-297.

Baron-Cohen, S., Bowen, D.C., Holt, R.J., Allison, C., Auyeung, B., Lombardo, M.V., Smith, P., Lai, M.-C., 2015. The "Reading the Mind in the Eyes" Test: Complete Absence of Typical Sex Difference in ~400 Men and Women with Autism. PLOS ONE 10, e0136521.

Baron-Cohen, S., Jolliffe, T., Mortimore, C., Robertson, M., 1997a. Another advanced test of theory of mind: evidence from very high functioning adults with autism or asperger syndrome. Journal of Child Psychology and Psychiatry 38, 813-822.

Baron-Cohen, S., Jolliffe, T., Mortimore, C., Robertson, M., 1997b. Another advanced test of theory of mind: Evidence from very high functioning adults with autism or Asperger syndrome. Journal of Child Psychology and Psychiatry and Allied Disciplines 38, 813-822.

Baron-Cohen, S., Leslie, A.M., Frith, U., 1985. Does the autistic child have a “theory of mind” ? Cognition 21, 37-46.

Baron-Cohen, S., Wheelwright, S., Hill, J., Raste, Y., Plumb, I., 2001. The “Reading the Mind in the Eyes” Test revised version: a study with normal adults, and adults with Asperger syndrome or high-functioning autism. Journal of Child Psychology and Psychiatry and Allied Disciplines 42, 241-251.

Baron-Cohen, S., Wheelwright, S., Jolliffe, T., 1997c. Is there a "language of the eyes"? Evidence from normal adults, and adults with autism or Asperger Syndrome. Visual Cognition 4, 311-331.

Beaumont, R., Newcombe, P., 2006. Theory of mind and central coherence in adults with high-functioning autism or Asperger syndrome. Autism 10, 365-382.

Begeer, S., Malle, B.F., Nieuwland, M.S., Keysar, B., 2010. Using theory of mind to represent and take part in social interactions: Comparing individuals with high-functioning autism and typically developing controls. European Journal of Developmental Psychology 7, 104-122.

Begg, C.B., Mazumdar, M., 1994. Operating characteristics of a rank correlation test for publication bias. Biometrics, 1088-1101.

Bentz, M., Jepsen, J.R., Pedersen, T., Bulik, C.M., Pedersen, L., Pagsberg, A.K., Plessen, K.J., 2017a. Impairment of Social Function in Young Females With Recent-Onset Anorexia Nervosa and Recovered Individuals. Journal of Adolescent Health 60, 23-32.

Bentz, M., Jepsen, J.R.M., Kjaersdam Telléus, G., Moslet, U., Pedersen, T., Bulik, C.M., Plessen, K.J., 2017b. Neurocognitive functions and social functioning in young females with recent-onset anorexia nervosa and recovered individuals. Journal of Eating Disorders 5, 5.

Beversdorf, D.Q., Anderson, J.M., Manning, S.E., Anderson, S.L., Nordgren, R.E., Felopulos, G.J., Nadeau, S.E., Heilman, K.M., Bauman, M.L., 1998. The effect of semantic and emotional context on written recall for verbal language in high functioning adults with autism spectrum disorder. Journal of Neurology Neurosurgery and Psychiatry 65, 685-692.

Blackshaw, A.J., Kinderman, P., Hare, D.J., Hatton, C., 2001. Theory of mind, causal attribution and paranoia in Asperger syndrome. Autism 5, 147-163.

Bora, E., Kose, S., 2016. Meta-analysis of theory of mind in anorexia nervosa and bulimia nervosa: A specific Impairment of cognitive perspective taking in anorexia nervosa? International Journal of Eating Disorders 49, 739-740.

Boucher, J., 2012. Research Review: Structural language in autistic spectrum disorder – characteristics and causes. Journal of Child Psychology and Psychiatry 53, 219-233.

Bowler, D.M., 1992. 'Theory of mind' in Asperger's syndrome. Journal of Child Psychology and Psychiatry and Allied Disciplines 33, 877-893.

Brewer, N., Young, R.L., Barnett, E., 2017. Measuring Theory of Mind in Adults with Autism Spectrum Disorder. Journal of Autism and Developmental Disorders 47, 1927-1941.

Brockmeyer, T., Pellegrino, J., Munch, H., Herzog, W., Dziobek, I., Friederich, H., 2016. Social cognition in anorexia nervosa: Specific difficulties in decoding emotional but not nonemotional mental states. International Journal of Eating Disorders 49, 883-890.

Brown, H.M., Klein, P.D., 2011. Writing, asperger syndrome and theory of mind. Journal of Autism and Developmental Disorders 41, 1464-1474.

Brugha, T.S., McManus, S., Bankart, J., et al., 2011. Epidemiology of autism spectrum disorders in adults in the community in england. Archives of General Psychiatry 68, 459-465.

Brunsdon, V.E., Colvert, E., Ames, C., Garnett, T., Gillan, N., Hallett, V., Lietz, S., Woodhouse, E., Bolton, P., Happe, F., 2015. Exploring the cognitive features in children with autism spectrum disorder, their co-twins, and typically developing children within a population-based sample. Journal of child psychology and psychiatry, and allied disciplines 56, 893-902.

Caglar-Nazali, P., Corfield, F., Cardi, V., Ambwani, S., Leppanen, J., Olabintan, O., Deriziotis, S., Hadjimichalis, A., Scognamiglio, P., Eshkevari, E., Micali, N., Treasure, J., 2014. A systematic review and meta-analysis of 'Systems for Social Processes' in eating disorders. Neuroscience and Biobehavioral Review 42, 55-92.

Callenmark, B., Kjellin, L., Ronnqvist, L., Bolte, S., 2014. Explicit versus implicit social cognition testing in autism spectrum disorder. Autism 18, 684-693.

Calvo Sagardoy, R., Gallego Morales, L.T., Solorzano Ostolaza, G., Kassem Garcia, S., Morales Martinez, C., Codesal Julian, R., Blanco Fernandez, A., 2014. [Emotional processing in adult vs adolescent patients with eating behavior disorders; emotional recognizing and the mental theory]. Procesamiento emocional en pacientes con trastornos de conducta alimentaria adultas vs adolescentes; reconocimiento emocional y teoria de la mente. 29, 941-952.

Cardi, V., Di Matteo, R., Corfield, F., Treasure, J., 2013. Social reward and rejection sensitivity in eating disorders: an investigation of attentional bias and early experiences. The world journal of biological psychiatry : Journal of the World Federation of Societies of Biological Psychiatry 14, 622-633.

Cardi, V., Turton, R., Schifano, S., Leppanen, J., Hirsch, C.R., Treasure, J., 2017. Biased Interpretation of Ambiguous Social Scenarios in Anorexia Nervosa. European Eating Disorders Review 25, 60-64.

Chevallier, C., Grèzes, J., Molesworth, C., Berthoz, S., Happé, F., 2012a. Brief report: Selective social anhedonia in high functioning autism. Journal of Autism and Developmental Disorders 42, 1504-1509.

Chevallier, C., Kohls, G., Troiani, V., Brodkin, E.S., Schultz, R.T., 2012b. The social motivation theory of autism. Trends in Cognitive Sciences 16, 231-239.

Colle, L., Baron-Cohen, S., Hill, J., 2007. Do Children with Autism have a Theory of Mind? A Non-verbal Test of Autism vs. Specific Language Impairment. Journal of Autism and Developmental Disorders 37, 716-723.

Cook, R.D., Weisberg, S., 1982. Residuals and influence in regression. New York: Chapman and Hall.

Corcoran, R., Mercer, G., Frith, C.D., 1995. Schizophrenia, symptomatology and social inference: Investigating “theory of mind” in people with schizophrenia. Schizophrenia Research 17, 5-13.

Craig, J.S., Hatton, C., Craig, F.B., Bentall, R.P., 2004. Persecutory beliefs, attributions and theory of mind: Comparison of patients with paranoid delusions, Asperger's syndrome and healthy controls. Schizophrenia Research 69, 29-33.

Crane, L., Goddard, L., Pring, L., 2013. Autobiographical memory in adults with autism spectrum disorder: The role of depressed mood, rumination, working memory and theory of mind. Autism 17, 205-219.

Dapelo, M.M., Surguladze, S., Morris, R., Tchanturia, K., 2016. Emotion Recognition in Blended Facial Expressions in Women with Anorexia Nervosa. European Eating Disorders Review 24, 34-42.

Davies, H., Wolz, I., Leppanen, J., Fernandez-Aranda, F., Schmidt, U., Tchanturia, K., 2016. Facial expression to emotional stimuli in non-psychotic disorders: A systematic review and meta-analysis. Neuroscience and Biobehavioral Reviews 64, 252-271.

Demurie, E., De Corel, M., Roeyers, H., 2011. Empathic accuracy in adolescents with autism spectrum disorders and adolescents with attention-deficit/hyperactivity disorder. Research in Autism Spectrum Disorders 5, 126-134.

Dewey, M., 1998. Att leva med Aspergers syndrom, in: Frith, U. (Ed.), Autism och Asperger syndrom. Stockholm: Liber. Liber, Stockholm, pp. 234-263.

Dziobek, I., Fleck, S., Kalbe, E., Rogers, K., Hassenstab, J., Brand, M., Kessler, J., Woike, J.K., Wolf, O.T., Convit, A., 2006a. Introducing MASC: A movie for the assessment of social cognition. Journal of Autism and Developmental Disorders 36, 623-636.

Dziobek, I., Fleck, S., Rogers, K., Wolf, O.T., Convit, A., 2006b. The 'amygdala theory of autism' revisited: Linking structure to behavior. Neuropsychologia 44, 1891-1899.

Evers, K., Steyaert, J., Noens, I., Wagemans, J., 2015. Reduced Recognition of Dynamic Facial Emotional Expressions and Emotion-Specific Response Bias in Children with an Autism Spectrum Disorder. Journal of Autism and Developmental Disorders 45, 1774-1784.

Flood, A.M., Julian Hare, D., Wallis, P., 2011. An investigation into social information processing in young people with Asperger syndrome. Autism 15, 601-624.

Frith, C., Frith, U., 2005. Theory of mind. Current Biology 15, R644-R645.

Gal, Z., Egyed, K., Paszthy, B., Nemeth, D., 2011. [Impaired theory of mind in anorexia nervosa]. Psychiatria Hungarica : A Magyar Pszichiatriai Tarsasag tudomanyos folyoirata 26, 12-25.

Ganz, J.B., Flores, M.M., 2009. The Effectiveness of Direct Instruction for Teaching Language to Children with Autism Spectrum Disorders: Identifying Materials. Journal of Autism and Developmental Disorders 39, 75-83.

Gillberg, I.C., Billstedt, E., Wentz, E., Anckarsater, H., Rastam, M., Gillberg, C., 2010. Attention, executive functions, and mentalizing in anorexia nervosa eighteen years after onset of eating disorder. Journal of Clinical and Experimental Neuropsychology 32, 358-365.

Golan, O., Baron-Cohen, S., Hill, J.J., Golan, Y., 2006. The "reading the mind in films" task: complex emotion recognition in adults with and without autism spectrum conditions. Social Neuroscience 1, 111-123.

Golan, O., Baron-Cohen, S., Hill, J.J., Rutherford, M.D., 2007. The 'Reading the Mind in the Voice' test-revised: A study of complex emotion recognition in adults with and without autism spectrum conditions. Journal of Autism and Developmental Disorders 37, 1096-1106.

Gonzalez-Gadea, M.L., Baez, S., Torralva, T., Castellanos, F.X., Rattazzi, A., Bein, V., Rogg, K., Manes, F., Ibanez, A., 2013. Cognitive variability in adults with ADHD and AS: Disentangling the roles of executive functions and social cognition. Research in Developmental Disabilities 34, 817-830.

Grainger, C., Williams, D.M., Lind, S.E., 2014. Metacognition, metamemory, and mindreading in high-functioning adults with autism spectrum disorder. Journal of Abnormal Psychology 123, 650-659.

Gregory, C., Lough, S., Stone, V., Erzinclioglu, S., Martin, L., Baron-Cohen, S., Hodges, J.R., 2002. Theory of mind in patients with frontal variant frontotemporal dementia and Alzheimer's disease: theoretical and practical implications. Brain 125, 752-764.

Happe, F.G., 1994. An advanced test of theory of mind: understanding of story characters' thoughts and feelings by able autistic, mentally handicapped, and normal children and adults. Journal of Autism and Developmental Disorders 24, 129-154.

Harrison, A., Genders, R., Davies, H., Treasure, J., Tchanturia, K., 2011. Experimental measurement of the regulation of anger and aggression in women with anorexia nervosa. Clinical Psychology and Psychotherapy 18, 445-452.

Harrison, A., Mountford, V.A., Tchanturia, K., 2014. Social anhedonia and work and social functioning in the acute and recovered phases of eating disorders. Psychiatry Research 218, 187-194.

Harrison, A., Sullivan, S., Tchanturia, K., Treasure, J., 2009. Emotion recognition and regulation in anorexia nervosa. Clinical Psychology and Psychotherapy 16, 348-356.

Harrison, A., Sullivan, S., Tchanturia, K., Treasure, J., 2010a. Emotional functioning in eating disorders: attentional bias, emotion recognition and emotion regulation. Psychological Medicine, 1-11.

Harrison, A., Tchanturia, K., Treasure, J., 2010b. Attentional bias, emotion recognition, and emotion regulation in anorexia: State or trait? Biological Psychiatry 68, 755-761.

Heavey, L., Phillips, W., Baron-Cohen, S., Rutter, M., 2000. The awkward moments test: A naturalistic measure of social understanding in autism. Journal of Autism and Developmental Disorders 30, 225-236.

Hedges, L.V., 1981. Distribution Theory for Glass's Estimator of Effect size and Related Estimators. Journal of Educational and Behavioral Statistics 6, 107-128.

Heider, F., Simmel, M., 1944. An experimental study of apparent behavior. The American Journal of Psychology 57, 243-259.

Huke, V., Turk, J., Saeidi, S., Kent, A., Morgan, J.F., 2013. Autism Spectrum Disorders in Eating Disorder Populations: A Systematic Review. European Eating Disorders Review 21, 345-351.

Jameel, L., Vyas, K., Bellesi, G., Cassell, D., Channon, S., 2015. Great Expectations: The Role of Rules in Guiding Pro-social Behaviour in Groups with High Versus Low Autistic Traits. Journal of Autism and Developmental Disorders 45, 2311-2322.

Jermakow, N., Brzezicka, A., 2016. How autistic are anorectic females? Similarities and differences between anorexia nervosa and autism spectrum disorders. Clinical Neuropsychiatry 13, 53-58.

Johnston, L., Miles, L., McKinlay, A., 2008. A critical review of the eyes test as a measure of social ‐ cognitive impairment. Australian Journal of Psychology 60, 135-141.

Jolliffe, T., Baron-Cohen, S., 1999. The strange stories test: A replication with high-functioning adults with autism or Asperger syndrome. Journal of Autism and Developmental Disorders 29, 395-406.

Kanakam, N., Krug, I., Raoult, C., Collier, D., Treasure, J., 2013. Social and emotional processing as a behavioural endophenotype in eating disorders: A pilot investigation in twins. European Eating Disorders Review 21, 294-307.

Keys, A., Brožek, J., Henschel, A., Mickelsen, O., Taylor, H.L., 1950. The biology of human starvation. . University of Minnesota Press, Oxford, England.

Kipps, C.M., Hodges, J.R., 2006. Theory of mind in frontotemporal dementia. Social Neuroscience 1, 235-244.

Kleinman, J., Marciano, P., Ault, R., 2000. Advanced Theory of Mind in High-Functioning Adults with Autism. Journal of Autism and Developmental Disorders 31, 29-36.

Kleinman, J., Marciano, P.L., Ault, R.L., 2001. Advanced Theory of Mind in High-Functioning Adults with Autism. Journal of Autism and Developmental Disorders 31, 29-36.

Klin, A., 2000. Attributing social meaning to ambiguous visual stimuli in higher-functioning Autism and Asperger syndrome: The social attribution task. Journal of Child Psychology and Psychiatry and Allied Disciplines 41, 831-846.

Korkman, M., Kirk, U., Kemp, S.L., 2007a. NEPSY II. Administrative manual. Psychological Corporation, San Antonio, TX.

Korkman, M., Kirk, U., Kemp, S.L. , 2007b. NEPSY II. Clinical and interpretative manual. Psychological Corporation, San Antonio, TX.

Kristen, S., Rossmann, F., Sodian, B., 2014. Theory of own mind and autobiographical memory in adults with ASD. Research in Autism Spectrum Disorders 8, 827-837.

Kucharska, K., Jeschke, J., Mafi, R., 2016. Intact social cognitive processes in outpatients with anorexia nervosa: A pilot study. Annals of General Psychiatry 15, 24.

Kuusikko, S., Haapsamo, H., Jansson-Verkasalo, E., Hurtig, T., Mattila, M.-L., Ebeling, H., Jussila, K., Bölte, S., Moilanen, I., 2009. Emotion Recognition in Children and Adolescents with Autism Spectrum Disorders. Journal of Autism and Developmental Disorders 39, 938-945.

Laghi, F., Pompili, S., Zanna, V., Castiglioni, M.C., Criscuolo, M., Chianello, I., Baumgartner, E., Baiocco, R., 2015. Are adolescents with anorexia nervosa better at reading minds? Cognitive Neuropsychiatry 20, 489-501.

Lahera, G., Boada, L., Pousa, E., Mirapeix, I., Moron-Nozaleda, G., Marinas, L., Gisbert, L., Pamias, M., Parellada, M., 2014. Movie for the Assessment of Social Cognition (MASC): Spanish validation. Journal of Autism and Developmental Disorders 44, 1886-1896.

Lai, M.C., Lombardo, M.V., Ruigrok, A.N., Chakrabarti, B., Wheelwright, S.J., Auyeung, B., Allison, C., Baron-Cohen, S., 2012. Cognition in males and females with autism: similarities and differences. PLOS ONE 7, e47198.

Lane, R.D., Quinlan, D.M., Schwartz, G.E., Walker, P.A., Zeitlin, S.B., 1990. The Levels of Emotional Awareness Scale: a cognitive-developmental measure of emotion. Journal of Personality Assessment 55, 124-134.

Lehnhardt, F.G., Gawronski, A., Volpert, K., Schilbach, L., Tepest, R., Huff, W., Vogeley, K., 2011. Autism spectrum disorders in adulthood: Clinical and neuropsychological findings of aspergers syndrome diagnosed late in life. Fortschritte der Neurologie Psychiatrie 79, 290-297.

Leppanen, J., Cardi, V., Ng, K.W., Paloyelis, Y., Stein, D., Tchanturia, K., Treasure, J., 2017a. Effects of Intranasal Oxytocin on the Interpretation and Expression of Emotions in Anorexia Nervosa. Journal of Neuroendocrinology 29, 12458.

Leppanen, J., Dapelo, M.M., Davies, H., Lang, K., Treasure, J., Tchanturia, K., 2017b. Computerised analysis of facial emotion expression in eating disorders. PLOS ONE 12, e0178972.

Lever, A.G., Geurts, H.M., 2015. Age-related differences in cognition across the adult lifespan in autism spectrum disorder. Autism Research.

Lind, S.E., Williams, D.M., Raber, J., Peel, A., Bowler, D.M., 2014. Spatial navigation impairments among intellectually high-functioning adults with autism spectrum disorder: exploring relations with theory of mind, episodic memory, and episodic future thinking. Journal of Abnormal Psychology 122, 1189-1199.

Lombardo, M.V., Barnes, J.L., Wheelwright, S.J., Baron-Cohen, S., 2007. Self-referential cognition and empathy in austism. PLOS ONE 2.

Loomes, R., Hull, L., Mandy, W.P.L., 2017. What Is the Male-to-Female Ratio in Autism Spectrum Disorder? A Systematic Review and Meta-Analysis. Journal of the American Academy of Child and Adolescent Psychiatry 56, 466-474.

Loveland, K.A., Tunali-Kotoski, B., Pearson, D.A., Brelsford, K.A., Ortegon, J., Chen, R., 2008. Imitation and expression of facial affect in autism. Development and Psychopathology 6, 433-444.

Lugnegard, T., Unenge Hallerback, M., Hjarthag, F., Gillberg, C., 2013. Social cognition impairments in Asperger syndrome and schizophrenia. Schizophrenia Research 143, 277-284.

Marsh, L.E., Hamilton, A.F., 2011. Dissociation of mirroring and mentalising systems in autism. Neuroimage 56, 1511-1519.

Martin, I., McDonald, S., 2004. An exploration of causes of non-literal language problems in individuals with Asperger syndrome. Journal of Autism and Developmental Disorders 34, 311-328.

Martinez, G., Alexandre, C., Mam-Lam-Fook, C., Bendjemaa, N., Gaillard, R., Garel, P., Dziobek, I., Amado, I., Krebs, M.O., 2017. Phenotypic continuum between autism and schizophrenia: Evidence from the Movie for the Assessment of Social Cognition (MASC). Schizophrenia Research 185, 161-166.

McDonald, S., Flanagan, S., Rollins, J., Kinch, J., 2003. TASIT: A new clinical tool for assessing social perception after traumatic brain injury. The Journal of Head Trauma Rehabilitation 18, 219-238.

McIntosh, D.N., Reichmann-Decker, A., Winkielman, P., Wilbarger, J.L., 2006. When the social mirror breaks: deficits in automatic, but not voluntary, mimicry of emotional facial expressions in autism. Developmental Science 9, 295-302.

Medina-Pradas, C., Navarro, J.B., Alvarez-Moya, E.M., Grau, A., Obiols, J.E., 2012. Emotional theory of mind in eating disorders. International Journal of Clinical and Health Psychology 12, 189-202.

Mendlewicz, L., Linkowski, P., Bazelmans, C., Philippot, P., 2005. Decoding emotional facial expressions in depressed and anorexic patients. Journal of Affective Disorders 89, 195-199.

Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G., The, P.G., 2009. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLOS Medicine 6, e1000097.

Muller, N., Baumeister, S., Dziobek, I., Banaschewski, T., Poustka, L., 2016. Validation of the Movie for the Assessment of Social Cognition in adolescents with ASD: Fixation duration and pupil dilation as predictors of performance. Journal of Autism and Developmental Disorders 46, 2831-2844.

Murray, H.A., 1943. Thematic apperception test. Harvard University Press, Cambridge, MA.

Murray, K., Johnston, K., Cunane, H., Kerr, C., Spain, D., Gillan, N., Hammond, N., Murphy, D., Happe, F., 2017. A new test of advanced theory of mind: The "strange stories film task" captures social processing differences in adults with autism spectrum disorders. Autism Research, No-Specified.

Myles, B.S., Barnhill, G.P., Hagiwara, T., Griswold, D.E., Simpson, R.L., 2001. A Synthesis of Studies on the Intellectual, Academic, Social/ Emotional and Sensory Characteristics of Children and Youth with Asperger Syndrome. Education and Training in Mental Retardation and Developmental Disabilities 36, 304-311.

Oakley, B.F., Brewer, R., Bird, G., Catmur, C., 2016. Theory of mind is not theory of emotion: A cautionary note on the reading the mind in the eyes test. Journal of Abnormal Psychology 125, 818-823.

Oldershaw, A., Hambrook, D., Stahl, D., Tchanturia, K., Treasure, J., Schmidt, U., 2011. The socio-emotional processing stream in Anorexia Nervosa. Neuroscience and Biobehavioral Reviews 35, 970-988.

Oldershaw, A., Hambrook, D., Tchanturia, K., Treasure, J., Schmidt, U., 2010. Emotional theory of mind and emotional awareness in recovered anorexia nervosa patients. Psychosomatic Medicine 72, 73-79.

Olofson, E.L., Casey, D., Oluyedun, O.A., Van Herwegen, J., Becerra, A., Rundblad, G., 2014. Youth with Autism Spectrum Disorder Comprehend Lexicalized and Novel Primary Conceptual Metaphors. Journal of Autism and Developmental Disorders 44, 2568-2583.

Pedreno, C., Pousa, E., Navarro, J.B., Pamias, M., Obiols, J.E., 2017. Exploring the Components of Advanced Theory of Mind in Autism Spectrum Disorder. Journal of Autism and Developmental Disorders 47, 2401-2409.

Postorino, V., Scahill, L., De Peppo, L., Fatta, L.M., Zanna, V., Castiglioni, M.C., Gillespie, S., Vicari, S., Mazzone, L., 2017. Investigation of Autism Spectrum Disorder and Autistic Traits in an Adolescent Sample with Anorexia Nervosa. Journal of Autism and Developmental Disorders 47, 1051-1061.

R Core Team, 2015. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria.

Robinson, S., Howlin, P., Russell, A., 2017. Personality traits, autobiographical memory and knowledge of self and others: A comparative study in young people with autism spectrum disorder. Autism 21, 357-367.

Rommel, D., Nandrino, J.-L., Antoine, P., Dodin, V., 2013. Emotional differentiation and parental bonding in inpatients suffering from eating disorders. Br J Clin Psychol 52, 215-229.

Rosenblau, G., Kliemann, D., Heekeren, H.R., Dziobek, I., 2015. Approximating implicit and explicit mentalizing with two naturalistic video-based tasks in typical development and autism spectrum disorder. Journal of Autism and Developmental Disorders 45, 953-965.

Rothschild-Yakar, L., Levy-Shiff, R., Fridman-Balaban, R., Gur, E., Stein, D., 2010. Mentalization and relationships with parents as predictors of eating disordered behavior. The Journal of Nervous and Mental Disease 198, 501-507.

Russell, T.A., Schmidt, U., Doherty, L., Young, V., Tchanturia, K., 2009. Aspects of social cognition in anorexia nervosa: Affective and cognitive theory of mind. Psychiatry Research 168, 181-185.

Rutherford, M.D., Baron-Cohen, S., Wheelwright, S., 2002. Reading the Mind in the Voice: A Study with Normal Adults and Adults with Asperger Syndrome and High Functioning Autism. Journal of Autism and Developmental Disorders 32, 189-194.

Samson, A.C., Hegenloh, M., 2010. Stimulus characteristics affect humor processing in individuals with asperger syndrome. Journal of Autism and Developmental Disorders 40, 438-447.

Sato, W., Uono, S., Kochiyama, T., Yoshimura, S., Sawada, R., Kubota, Y., Sakihama, M., Toichi, M., 2017. Structural correlates of reading the mind in the eyes in autism spectrum disorder. Frontiers in Human Neuroscience 11, 361.

Schaller, U., Rauh, R., 2017. What difference does it make? Implicit, explicit and complex social cognition in autism spectrum disorders. Journal of Autism and Developmental Disorders 47, 961-979.

Schneider, D., Slaughter, V.P., Bayliss, A.P., Dux, P.E., 2013. A temporally sustained implicit theory of mind deficit in autism spectrum disorders. Cognition 129, 410-417.

Schuwerk, T., Vuori, M., Sodian, B., 2015. Implicit and explicit Theory of Mind reasoning in autism spectrum disorders: the impact of experience. Autism 19, 459-468.

Segura, M., Pedreno, C., Obiols, J., Taurines, R., Pamias, M., Grunblatt, E., Gella, A., 2015. Neurotrophin blood-based gene expression and social cognition analysis in patients with autism spectrum disorder. Neurogenetics 16, 123-131.

Senju, A., Southgate, V., White, S., Frith, U., 2009. Mindblind eyes: An absence of spontaneous theory of mind in Asperger syndrome. Science 325, 883-885.

Shamay-Tsoory, S.G., 2008. Recognition of 'fortune of others' emotions in Asperger syndrome and high functioning autism. Journal of Autism and Developmental Disorders 38, 1451-1461.

Spek, A.A., Scholte, E.M., Van Berckelaer-Onnes, I.A., 2010. Theory of mind in adults with HFA and asperger syndrome. Journal of Autism and Developmental Disorders 40, 280-289.

Stone, V.E., Baron-Cohen, S., Knight, R.T., 1998. Frontal lobe contributions to theory of mind. Journal of Cognitive Neuroscience 10, 640-656.

Tager-Flusberg, H., Caronna, E., 2007. Language Disorders: Autism and Other Pervasive Developmental Disorders. Pediatric Clinics of North America 54, 469-481.

Tapajoz Pereira De Sampaio, F., Soneira, S., Aulicino, A., Allegri, R.F., 2013a. Theory of mind in eating disorders and their relationship to clinical profile. European Eating Disorders Review 21, 479-487.

Tapajoz Pereira De Sampaio, F., Soneira, S., Aulicino, A., Martese, G., Iturry, M., Allegri, R.F., 2013b. Theory of mind and central coherence in eating disorders: two sides of the same coin? Psychiatry Research 210, 1116-1122.

Tchanturia, K., Davies, H., Harrison, A., Fox, J.R., Treasure, J., Schmidt, U., 2012. Altered social hedonic processing in eating disorders. International Journal of Eating Disorders 45, 962-969.

Tchanturia, K., Happé, F., Godley, J., Treasure, J., Bara-Carril, N., Schmidt, U., 2004. 'Theory of mind' in anorexia nervosa. European Eating Disorders Review 12, 361-366.

Torralva, T., Gleichgerrcht, E., Roca, M., Ibanez, A., Marenco, V., Rattazzi, A., Manes, F., 2013. Impaired theory of mind but intact decision-making in Asperger syndrome: Implications for the relationship between these cognitive domains. Psychiatry Research 205, 282-284.

Treasure, J., Schmidt, U., 2013. The cognitive-interpersonal maintenance model of anorexia nervosa revisited: a summary of the evidence for cognitive, socio-emotional and interpersonal predisposing and perpetuating factors. Journal of Eating Disorders 1, 13.

Uljarevic, M., Hamilton, A., 2013. Recognition of Emotions in Autism: A Formal Meta-Analysis. Journal of Autism and Developmental Disorders 43, 1517-1526.

Vagni, D., Moscone, D., Travaglione, S., Cotugno, A., 2016. Using the Ritvo Autism Asperger Diagnostic Scale-Revised (RAADS-R) disentangle the heterogeneity of autistic traits in an Italian eating disorder population. Research in Autism Spectrum Disorders 32, 143-155.

Viechtbauer, W., 2010. Conducting meta-analyses in R with the metafor package. Journal of Statistical Software 36, 1-48.

Viechtbauer, W., Cheung, M.W.L., 2010. Outlier and influence diagnostics for meta ‐ analysis. Research Synthesis Methods 1, 112-125.

Wellman, H.M., Liu, D., 2004. Scaling of theory-of-mind tasks. Child Development 75, 523-541.

Westen, D., 1995. Social Cognition and Object Relations Scale: Q-sort for projective stories (SCORS–Q), Unpublished manuscript Department of Psychiatry, The Cambridge Hospital and Harvard Medical School, Cambridge, MA.

Westwood, H., Mandy, W., Simic, M., Tchanturia, K., 2017a. Assessing ASD in Adolescent Females with Anorexia Nervosa using Clinical and Developmental Measures: a Preliminary Investigation. Journal of Abnormal Child Psychology.

Westwood, H., Mandy, W., Tchanturia, K., 2017b. The association between symptoms of autism and neuropsychological performance in females with Anorexia Nervosa. Psychiatry Research.

Westwood, H., Mandy, W., Tchanturia, K., 2017c. Clinical evaluation of autistic symptoms in women with anorexia nervosa. Molecular Autism 8, 12.

White, S., Frith, U., Rellecke, J., Al-Noor, Z., Gilbert, S., 2014. Autistic adolescents show atypical activation of the brain's mentalizing system even without a prior history of mentalizing problems. Neuropsychologia 56, 17-25.

White, S.J., Coniston, D., Rogers, R., Frith, U., 2011. Developing the Frith-Happe animations: A quick and objective test of Theory of Mind for adults with autism. Autism Research 4, 149-154.

Wilson, C.E., Happe, F., Wheelwright, S.J., Ecker, C., Lombardo, M.V., Johnston, P., Daly, E., Murphy, C.M., Spain, D., Lai, M.-C., Chakrabarti, B., Sauter, D.A., Baron-Cohen, S., Murphy, D.G.M., 2014. The neuropsychology of male adults with high-functioning Autism or Asperger syndrome. Autism Research 7, 568-581.

Yeh, Z.T., Liu, S.I., Wang, J.E., Huang, H.C., Chen, K.H., Wang, P.C., 2010. Nonverbal deficit to understand others' minds in high function autism spectrum disorders. Chinese Science Bulletin 55, 594-599.

Zalla, T., Leboyer, M., 2011. Judgment of intentionality and moral evaluation in individuals with high functioning autism. Review of Philosophy and Psychology 2, 681-698.

Zalla, T., Miele, D., Leboyer, M., Metcalfe, J., 2015. Metacognition of agency and theory of mind in adults with high functioning autism. Consciousness and Cognition 31, 126-138.

Zalla, T., Sav, A.M., Stopin, A., Ahade, S., Leboyer, M., 2009. Faux pas detection and intentional action in asperger syndrome. A replication on a French sample. Journal of Autism and Developmental Disorders 39, 373-382.

Zalla, T., Sperduti, M., Girardi, G., Chelini, C., Leboyer, M., Bourgeois-Gironde, S., 2016. Reduced social coordination in Autism Spectrum Disorders. Research in Autism Spectrum Disorders 26, 71-79.

Zhang, Z., Xu, X., Ni, H., 2013. Small studies may overestimate the effect sizes in critical care meta-analyses: a meta-epidemiological study. Critical care (London, England) 17, R2.

10 Figure legends

Figure 1. Study selection flow charts. A. The study selection flow chart of studies investigating theory of mind in autism spectrum disorders. B. The study selection flow chart of studies investigating theory of mind in anorexia nervosa.

Figure 2. Emotional theory of mind in ASD.

ASD = autism spectrum disorder; AS = Asperger's Disorder; HFA = high functioning autism; F = female; M = male; AoE = Arena of Emotions; A-ToM = Animated Theory of Mind test; C-ToM = Computerised Theory of Mind test; MASC – Emotions = Emotions category of the Movie for the Assessment of Social Cognition; RMET = Reading the Mind in the Eyes Test; RMFT = Reading the Mind in the Film Test; RMVT = Reading the Mind in the Voice Test; SMD = standardised mean difference; CI = Confidence interval.

Figure 3. Emotional theory of mind in AN.

AN = anorexia nervosa; EDNOS = Eating Disorder Not Otherwise Specified; Levels of Emotional Awareness Scale; MASC – Emotions = Emotions category of the Movie for the Assessment of Social Cognition; RMET = Reading the Mind in the Eyes Test; RMFT = Reading the Mind in the Film Test; RMVT = Reading the Mind in the Voice Test; SMD = standardised mean difference; CI = Confidence interval. Calvo Sagardoy et al. (2014) A = adolescent participants; Calvo Sagardoy et al. (2014) B = adult participants.

Figure 4. Understanding of simple social interactions in ASD and AN.

ASD = autism spectrum disorder; AS = Asperger's Disorder; HFA = high functioning autism; AN = anorexia nervosa; AMT = Awkward Moments Test; A-ToM = Animated Theory of Mind test;

DST = Dewey Story Test; FBT = False Belief Test; FPT = Faux Pas Test; ToM Scale = Theory of Mind Scale; NEPSY-II = A Developmental NEuroPSYchological Assessment second edition; SMD = standardised mean difference; CI = Confidence interval.

Figure 5. Understanding of complex social interactions in ASD and AN.

ASD = autism spectrum disorder; AS = Asperger's Disorder; HFA = high functioning autism; AN = anorexia nervosa; AN-REC = Recovered from anorexia nervosa; C-ToM = Computerised Theory of Mind test; MASC = Movie for the Assessment of Social Cognition; PIS = Pragmatic Interpretation Stories; SST = Strange Stories Test; SCORS = Social Cognition and Object Relation; TASIT = The Awareness of Social Inference Test; SMD = standardised mean difference; CI = Confidence interval.

Figure 6. Implicit social attribution in ASD and AN.

ASD = autism spectrum disorder; AS = Asperger's Disorder; HFA = high functioning autism; AN = anorexia nervosa; AN-REC = Recovered from anorexia nervosa; AN-WR = Weight restored people with anorexia nervosa; PIT = Projective Imagination Test; SAT = Social attribution Test; SHA = Smith-Happé Animations; TAT = Thematic Apperception Test; SMD = standardised mean difference; CI = Confidence interval.